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WEEKLY 9 March 2024

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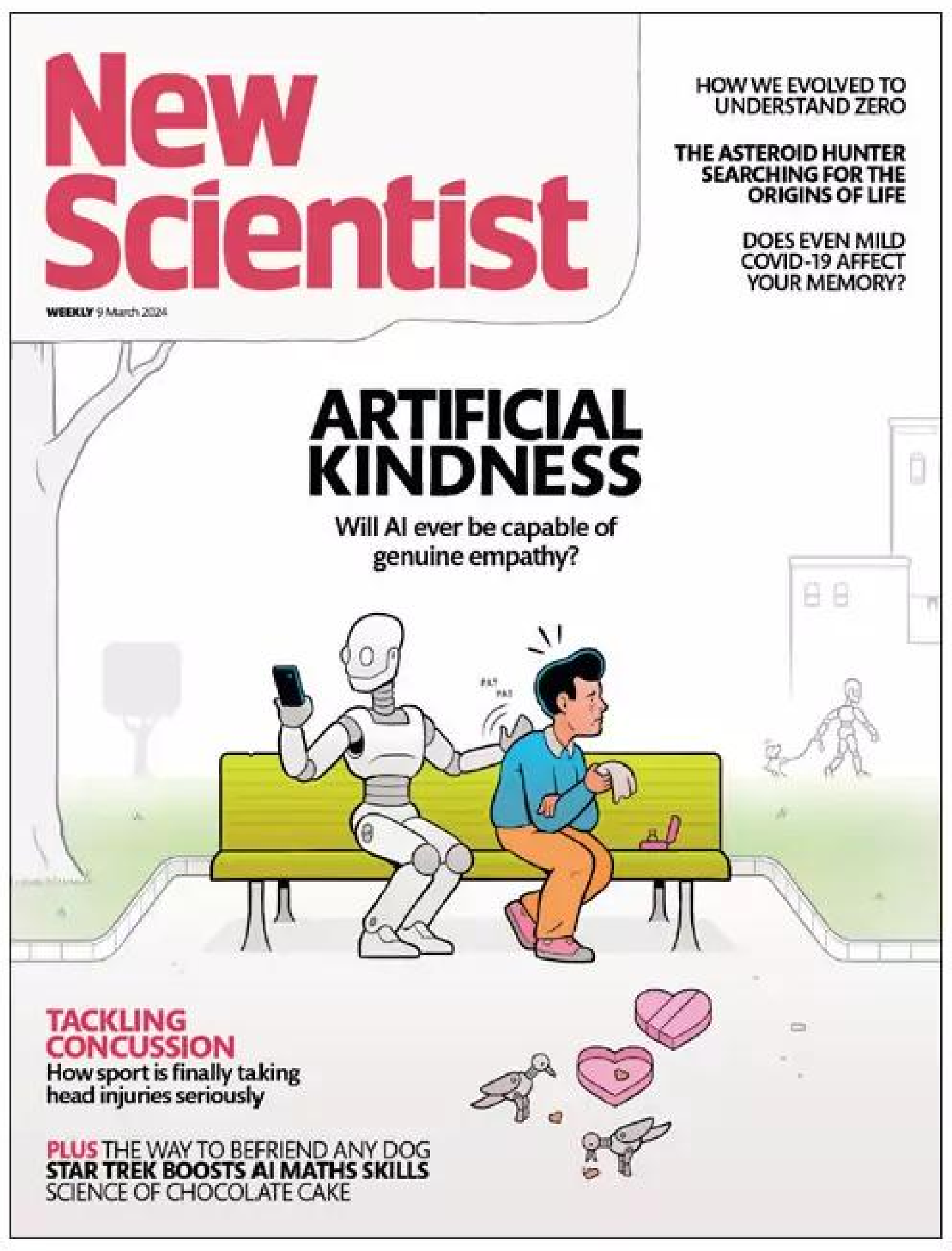
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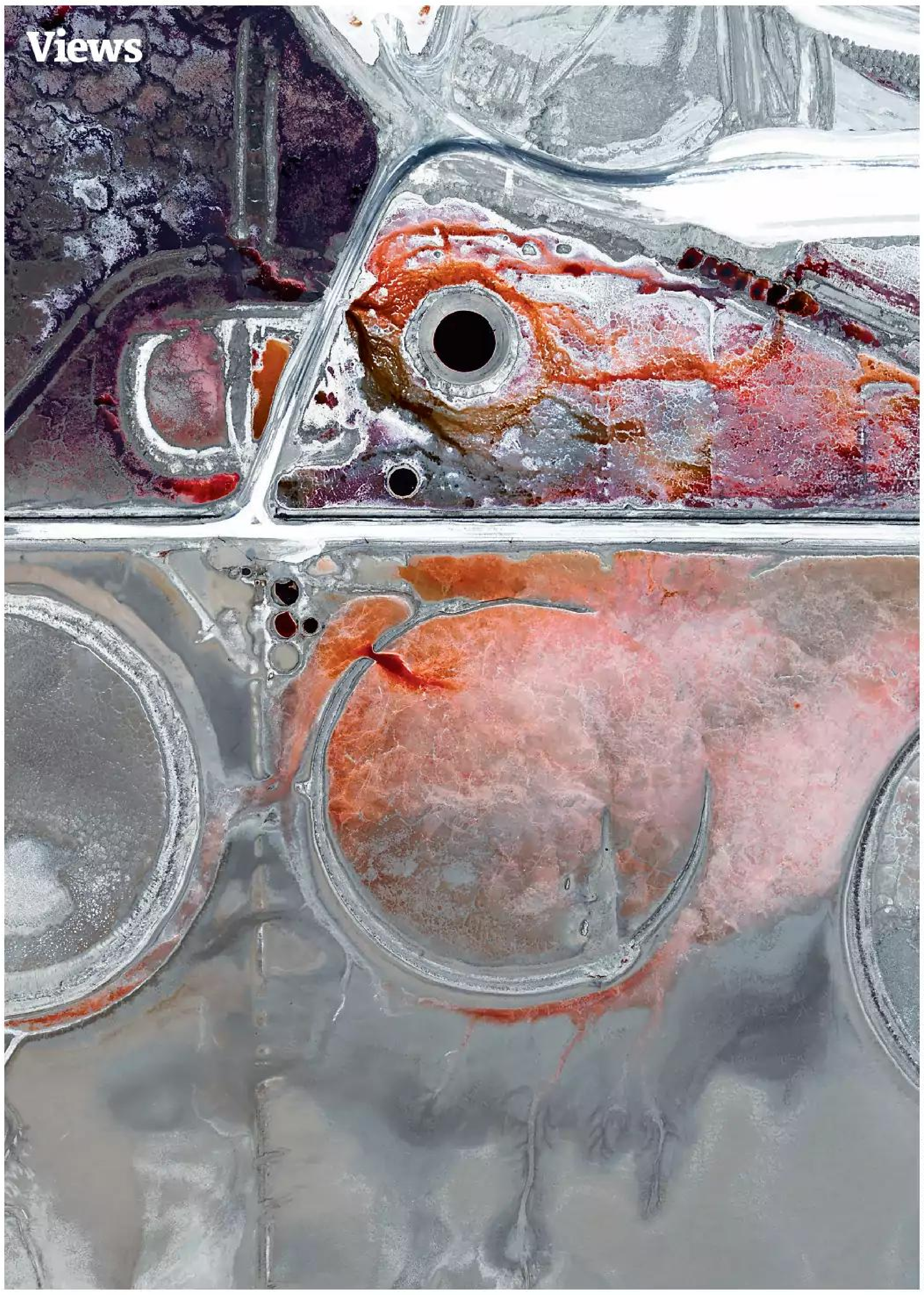

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Virtual event

The road to conscious machines

Public debate about artificial intelligence often centres on the idea of a dystopian robot takeover. Michael Wooldridge, a computer scientist at the University of Oxford, will instead explore how our anxieties distract us from the immediate risks that AI poses – from algorithmic bias to fake news. This subscriber-only virtual event takes place on 12 March at 6pm GMT/1pm EST.

newscientist.com/events

Tour

Niels Bohr's Copenhagen, Denmark

Join journalist Manjit Kumar on a journey to the birthplace of quantum physics. Explore the sites where Niels Bohr formed his ideas about atomic structure and quantum theory, and find out how he became part of the Manhattan Project that made the atomic bomb. Then enjoy a day trip to the ancient city of Roskilde – now a centre for sustainable energy research. This six-day tour starts on 3 July and costs £2698.

newscientist.com/tours

Podcast

Weekly

The team consider whether personalised medicine has been overhyped and discuss how a famed mathematician may have got music all wrong. Also hear how your brain grapples with the concept of nothing. Plus, there is new research on a poop-based climate solution and some top tips on how to befriend a dog.

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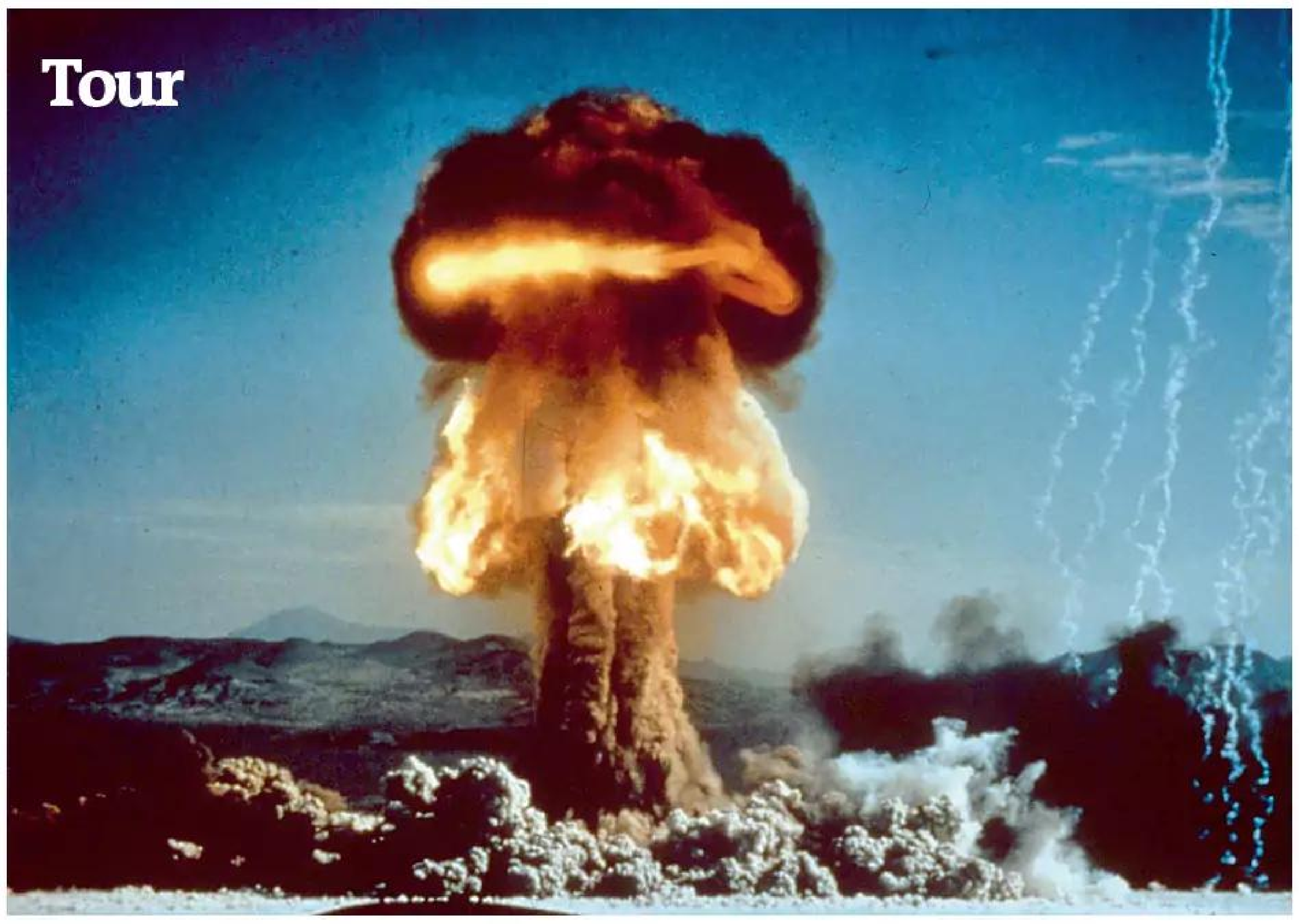
Marine snow Plankton poop takes carbon out of the atmosphere



DENIS CAMERON/SHUTTERSTOCK

Chain reaction Discover Niels Bohr's influence on the atomic age

Video

Make some noise

Danionella cerebrum is a species of fish native to small streams in the Bago Yoma mountain range in Myanmar. Though only around 12 millimetres long and with the smallest brain of any vertebrate, they can produce a drumming sound that registers at more than 140 decibels – about as loud as exploding firecrackers. Researchers have now figured out how.

youtube.com/newscientist

Newsletter

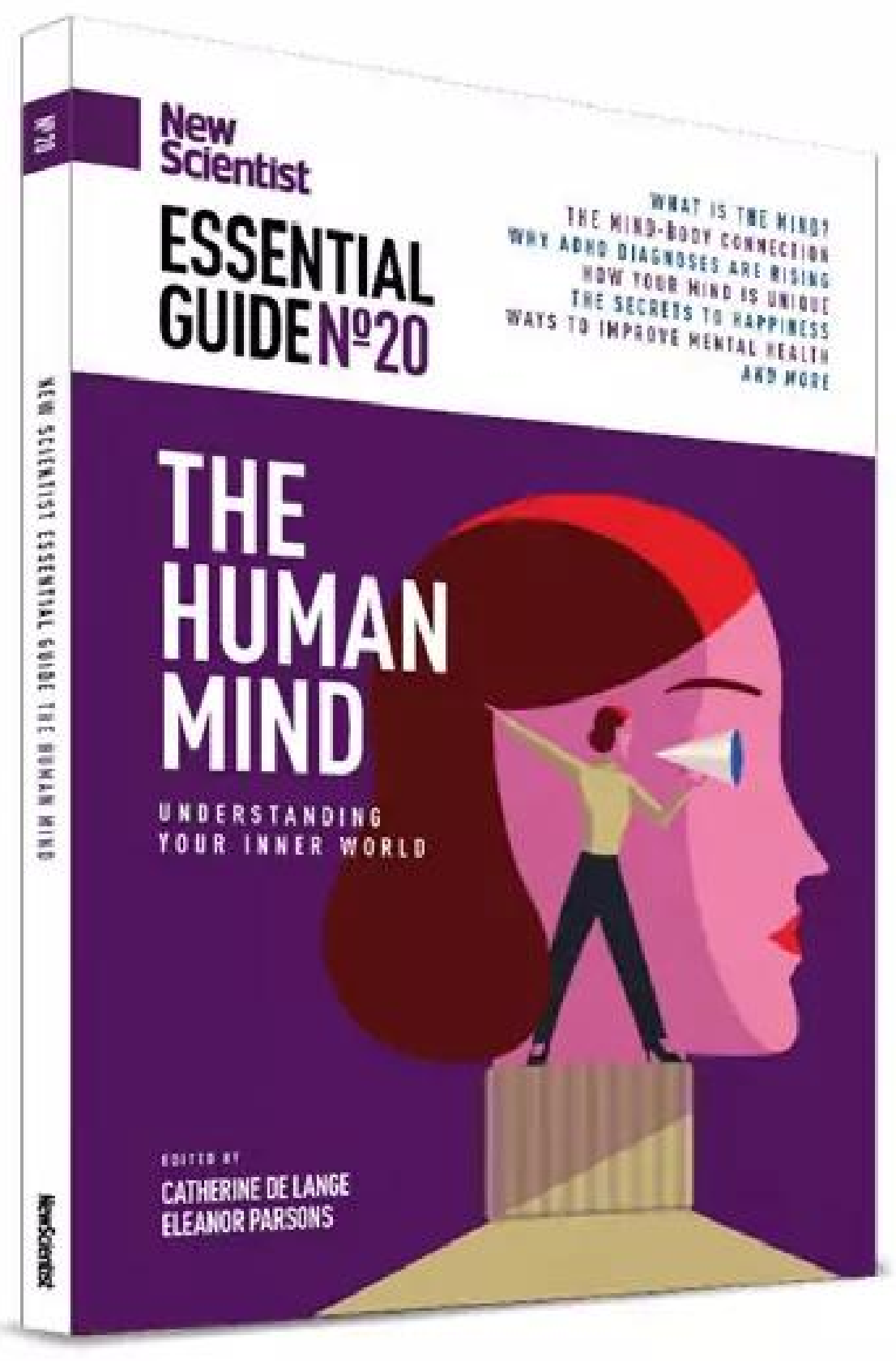
Launchpad

The tiniest things in our universe can have a colossal impact. In this latest Launchpad, Leah Crane explores how dust particles not only obscure our view through telescopes but also have a profound effect on pretty much everything in the cosmos – from stars to planets and even the origin of life.

newscientist.com/launchpad

Newsletter

> **"Dusty pools could potentially have been the sources of the first life on our world"**



Essential guide

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Open science

We should discuss controversial research in public to avoid a backlash

SCIENTIFIC advances and societal norms rarely progress at the same pace, a mismatch that is behind some of the biggest controversies in science, from the theory of evolution to genetically modified foods. Should scientists be doing more to take the public with them as research fields develop?

Researchers behind a high-tech advance in healthcare (see page 9) should be praised for their open approach. The work involves obtaining cells that have been shed by a fetus in the uterus and coaxing them into forming tiny balls of tissue, sometimes called "mini-organs" or organoids. Studying these structures could one day let doctors treat children born with various medical conditions.

Organoids – usually made from adult cells – have been used in research for a little over a decade. Because they seem closer to real human organs than cells grown in a single layer on the bottom of a dish, they already make some feel squeamish. Add fetuses into the mix and it only raises the potential for controversy.

> "Should scientists be doing more to take the public with them as research fields develop?"

But really, there is no cause for alarm. While the field accepts the need for caution with brain organoids – in case they one day approach some kind of sentience – those resembling other organs should raise no more ethical concerns than a tissue biopsy stored in a fridge.

The goal of this fetal organoid research is to help children who would otherwise have a very poor quality of life. The technique is likely to be first applied to a lung condition where nearly a third of babies who have it don't survive for long after birth. Organoids have another benefit: those made from adult cells are already replacing some animal experiments. The field is therefore likely to lead to less suffering in the world, rather than more.

Nevertheless, when new technologies such as these arrive, it is right that scientists work to explain the details, so that the public can understand and debate what is going on. No matter how uneasy it makes some people, transparency is the only way to prevent an anti-scientific backlash. ▮

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Not in harmony
Pythagoras was wrong about pleasant sounding music **p15**

SPACEX

Space

Bird's-eye view of a Starship

Shrouded in vapour, SpaceX's gleaming, stainless-steel Starship has undergone a final rehearsal before its next flight test later this month. The rocket and its Super Heavy booster, together standing 121 metres tall, were filled with a total of more than 4500 tonnes of liquid methane and liquid oxygen propellant for a fuelling test in Boca Chica, Texas.

Environment

Europe faces wave of hot summers

A big ice melt in Greenland last year could trigger hotter, drier weather in Europe this year and next, according to a study of the past four decades, finds **Michael Le Page**

THE 10 hottest and driest summers in Europe in the past 40 years have all followed the release of particularly large amounts of freshwater from Greenland's ice sheet, and this may mean an especially hot summer is coming in southern Europe this year.

The link between these events occurs because extra meltwater triggers a series of amplifying feedbacks that affect the strength and position of the atmospheric jet stream over Europe, according to Marilena Oltmanns at the National Oceanography Centre in Southampton, UK.

"2018 and 2022 were the most recent examples," she says. In 2022, there was extreme heat and many wildfires across Europe, with parts of the UK hitting 40°C (104°F) for the first time.

These feedback effects mean Europe is going to get even hotter and drier in coming decades as the melting of Greenland's ice sheet accelerates, in addition to the underlying warming trend resulting from fossil fuel emissions, says Oltmanns.

"This occurs on top of the warming that we already have because of increased greenhouse gases," she says.

Worse than feared

Although hotter heatwaves and drier droughts are expected as the planet warms, in some regions, such as Europe, recent heatwaves and droughts have been even more extreme than climate models projected.

Several studies have linked these extremes to the changes in the strength and position of the northern polar jet stream, a belt of high-level winds whose position and strength have a big influence on the weather in Europe.

BIOSPHOTO/ALAMY

Melting ice at the Sermilik fjord in eastern Greenland

But it hasn't been clear what is causing these changes, says Oltmanns. Now, she and her colleagues have analysed weather observations over the past 40 years, which they say show that the extremes are ultimately a result of periods of increased melting of Greenland ice.

"The statistical links based on the observations are very robust," she says.

The extra meltwater leads to a shallow layer of freshwater spreading south in the northern Atlantic Ocean. Because this layer is less likely to mix with the warmer, saltier water below, in winter the sea surface becomes colder than usual.

This leads to a more extreme gradient between this cold water and the warmer waters further south, which strengthens the weather fronts that form above this zone. That, in turn, strengthens wind patterns, which push warm water flowing north – known as the North Atlantic current – further north than usual. This amplifies the temperature gradient even more.

"These fronts that get created between the regions where we have cold freshwater and regions where we have warmer ocean water are the main energy source for storms," she says.

In a 2020 study, Oltmanns suggested that this process is leading to increased storminess during some winters.

Now, she and her team are suggesting that these winter changes have lasting effects in the following summers. "We still see significant signals two years after the freshwater anomaly has occurred," says Oltmanns.

> **"I think this summer we'll have strong heat anomalies over southern Europe"**

The stronger temperature gradient leads to a stronger jet stream across Europe, giving rise to hotter and drier weather in southern Europe, the team found. Then, as the abnormally cold water recedes, the jet stream shifts north, bringing hot, dry weather to northern Europe (*Weather and Climate Dynamics*, doi.org/mj5m).

"Individual links in this feedback chain have been discussed before," says Oltmanns. "What we have done in this study is put these links together."

This chain of feedbacks has been missed in computer models because they don't include factors such as the big variation in meltwater from year to year, she says.

"The proposed link in this study between Atlantic freshwater anomalies and subsequent summer weather over Europe is intriguing and relevant to current scientific research on long-range prediction of summer weather, particularly if the relationship holds in future summers," says Adam Scaife at the UK Met Office, the country's national weather service, who works on long-range forecasting.

"I think the study is somewhat convincing," says Fei Luo at the Centre for Climate Research Singapore. But observations of meltwater in the previous year won't be as good as looking at winter weather conditions when it comes to forecasting summer weather, she says.

Oltmanns, however, is confident enough to predict that, because of increased melting of Greenland ice during the summer of 2023, Europe is in for more heatwaves and droughts in the coming years. "I think this summer we'll have strong heat anomalies over southern Europe," she says.

These could be even stronger in 2025, and will then start to affect northern Europe. "We estimate that we will have another strong heatwave and drought not this year in northern Europe, but in the coming years," says Oltmanns ■

Health

Organoids made from uterus fluid could help treat medical conditions before birth

Clare Wilson

FETUSES with serious medical conditions could one day get better diagnoses and treatments while in the uterus, thanks to a technique that involves taking samples of cells from fluid in the uterus and growing them in a dish.

In a world first, Paolo De Coppi at Great Ormond Street Hospital in London and his colleagues have shown that fetal cells from amniotic fluid can be coaxed to form miniature balls of various types of tissue. They have also shown that these lung organoids could help guide the treatment of babies born with a sometimes-fatal lung condition called congenital diaphragmatic hernia (CDH).

The method hasn't been used to treat anyone, but the results show this is possible in principle, says De Coppi. It could also be modified to help in other congenital conditions in a type of personalised prenatal medicine.

GIUSEPPE CALA, PAOLO DE COPPI, MATTIA GERLI

A kidney organoid made from fetal cells in amniotic fluid

The idea exploits a recent approach in which cells in a dish are coaxed to grow into tissue organoids, about the size of a lentil, which take up a three-dimensional structure. These capture certain aspects of the tissue in question, including whether it is healthy or growing abnormally, better than the standard technique of growing cells in a two-dimensional layer.

De Coppi and his colleagues have now shown that samples of amniotic fluid taken during pregnancy contain fetal cells capable of forming organoids of tissue from the lungs, kidneys and small intestine.

Studying organoids made from cells from a fetus known to have a congenital condition may give doctors more information about what form it will take, how severe it is and how it could be treated.

In the study, the researchers created organoids for 12 fetuses with CDH, where the abdominal organs push up into the chest and stop the left lung growing properly. The condition can be treated while the fetus is in the uterus by pushing a balloon into the lung to expand it, helping it to develop better.

The researchers created lung organoids from the fetuses both before and after the balloon treatment. They saw hints that the organoids created after the treatment were behaving more like healthy lung tissue than the ones made beforehand, implying that the treatment was successful (*Nature Medicine*, doi.org/mj7s).

The organoid technique could therefore be used to monitor if the treatment has worked, as well as gauging if it is needed, as doctors only carry it out in the severest forms of the condition. "This has a lot of potential for functional diagnoses," says De Coppi.

12

Organoids were made for this many fetuses

"If you have the possibility to categorise a disease into mild, moderate or severe, that's a great achievement," says Cecilia Götherström at the Karolinska Institute in Stockholm, Sweden.

The work also suggests it might be possible to turn organoids into mature tissue for implanting into ill babies after birth, says Holm Schneider at University Hospital Erlangen in Germany. ▮

Technology

Smart glasses can 'hear' where you are looking

PROTOTYPE smart glasses can track people's eye movements using a technique similar to sonar, an approach that uses 95 per cent less power than other methods.

Virtual reality headsets like Apple Vision Pro and Meta Quest Pro use cameras pointing at the wearer's face to track eye movements. This offers high accuracy, typically estimating the angle of their gaze to within 1 degree, but consumes a lot of power.

Now, Ke Li at Cornell University in New York and his colleagues created a system called GazeTrak that tracks eye movements with sound, doing away with the need for cameras.

Tiny speakers, one for each eye, broadcast sound at a frequency above 18 kilohertz – outside the range of most people's hearing – towards the face, which is reflected and picked up by four microphones on each side of the glasses.

An artificial intelligence model can then interpret these sounds to unpick which direction the wearer's eyes are pointing, because of inconsistencies in the shape of people's eyeballs and eyelids.

"When you move your eyes, your reflected signal will be different," says Li. "So by analysing the differences between the signals, we can track your gaze movement. It's like in sonar systems."

CHENG ZHAN

The GazeTrak smart glasses follow eye movements with reflected sound

In tests with 20 participants, the glasses managed to track people's gaze with an error rate of just 3.6 degrees (arXiv, doi.org/mj5n). This is less accurate than current commercial devices, but accurate enough for most applications in virtual reality, gaming or user interfaces, say the researchers.

"There's still a gap. But I think we also have some room to improve the accuracy," says Li. "We'll certainly do some follow-up work to improve the performance."

Apart from using less power, the technique offers more privacy, as some users may not feel comfortable having a camera continually filming them just to track eye movement, the researchers say. They also expect it to cost less and add less weight to devices. ▮

Matthew Sparkes

Technology

Google launches quantum quest

A $5 million prize aims to help quantum computers live up to their potential

Alex Wilkins

GOOGLE and the XPRIZE Foundation are launching a $5 million competition to find practical uses for quantum computers that could actually benefit society. We already know that these machines can perform specific tasks faster than classical computers, after Google first claimed quantum advantage for its Sycamore processor in 2019. However, these demonstration tasks are simple benchmarks with no real-world applications.

"There's a lot of rather abstract mathematical problems where we can prove quantum computers give very, very large speed-ups," says Ryan Babbush at Google. "But a lot of the research community has been less focused on trying to match those more abstract quantum speed-ups to specific real-world applications, and to try to figure out how quantum computers could be used."

To that end, Google and the XPRIZE Foundation are urging researchers to come up with new quantum algorithms as part of a three-year competition. The winning entries could solve an existing problem, like finding a new battery electrolyte that vastly improves storage capacity, but it doesn't need to solve the problem in practice, says Babbush. Instead, researchers just need to show how an algorithm could be applied, detailing what quantum computing specifications are required. Alternatively, competitors could show how an existing quantum algorithm could be applied to a real-world problem not previously considered.

The prize will judge entrants' algorithms on a range of criteria, such as how large their impact could be, whether they tackle problems similar to those outlined in the United Nations Sustainable Development Goals, and how feasibly they can be run on machines that are available now or in the near-future.

A prize fund of $5 million will be split into a grand prize of $3 million shared between up to three winners, $1 million shared by up to five runners-up and $50,000 for each of 20 semi-finalists.

The prize could help shift the focus of researchers from looking at technical definitions of quantum advantage, like those demonstrated by Google or IBM, to real-world uses, says Nicolás Quesada at Montreal Polytechnic in Canada. "[The prize is] hitting the nail on the head that this is a very important problem," he says. "We need to figure out what to do with a quantum computer."

However, finding socially beneficial algorithms will require a better understanding of how quantum computers work, and how to deal with noise and errors, says Bill Fefferman at the University of Chicago. The prize doesn't address this foundational aspect, he says.

"I'm very optimistic, in principle, that we'll find algorithms that are really useful," says Fefferman. "I'm not as optimistic that, in the next three years, we'll be able to discover those algorithms and then also implement them on the current hardware that will exist."

The Quantum Computing Lab at Google's Quantum AI campus in Goleta, California

FREDERIC J. BROWN/AFP VIA GETTY IMAGES

Marine biology

Lone orca seen hunting a great white shark

AN INDIVIDUAL orca has been observed hunting a great white shark for the first time, killing its prey in under 2 minutes.

The orca was one of a pair of males named Port and Starboard that have been killing great white sharks in waters near South Africa since 2017. The case shows that orcas (*Orcinus orca*) don't need to hunt in packs to kill great white sharks (*Carcharodon carcharias*), themselves formidable predators.

Sightseers and scientists aboard two vessels filmed Starboard dispatching the 2.5-metre-long shark, then swimming past the boats carrying its liver in its mouth.

The incident happened last June near Seal Island, about 400 kilometres east of Cape Town, South Africa. The carcass of a second, larger great white shark washed up on the beach the next day, possibly the result of another solo kill (*African Journal of Marine Science*, doi.org/mj5p).

"It opens up the possibility that this pair could be responsible for killing more sharks than we initially believed," says Alison Towner at Rhodes University, South Africa.

It is unclear how many great white sharks are in South African waters, but large numbers have fled Gansbaai and False Bay, near Cape Town, in response to the orca attacks there. This has hampered shark-viewing tourism, and could have ecological ramifications.

For one thing, fewer great white sharks means there are more Cape fur seals (*Arctocephalus pusillus pusillus*), which hunt and kill endangered African penguins (*Spheniscus demersus*) or compete with them for food. It is also possible that Port and Starboard will teach their skills to other orcas, says Towner. Starboard was seen hunting sharks alongside other orcas in nearby Mossel Bay in 2022.

2 minutes

How long it took an orca called Starboard to kill a great white shark

"In South Africa, [solo hunting] adds significant pressure on white sharks, potentially reaching a tipping point they don't need," says Towner.

Ryan Truscott

Health

Lasting pain after a UTI may be due to excess nerve cells

Chen Ly

PAIN that persists even after a urinary tract infection has supposedly passed seems to be down to an overgrowth of nerve cells in the bladder.

Urinary tract infections (UTIs) are most commonly caused by the bacterium *Escherichia coli* making its way from faecal matter to the urethra, bladder or kidneys. Symptoms can include pain while urinating and the urge to urinate more often than normal. The infections mainly affect women, of whom around half develop a UTI at some point in their life.

"One of the major issues regarding urinary tract infections is its pretty high rate of recurrence," says Soman Abraham at Duke University in North Carolina. "But after treatment, some people seem to have the same UTI symptoms even when there's no longer an infection."

To investigate, Abraham and his colleagues analysed bladder tissue biopsies from eight women who reported continued pelvic pain from recurrent UTIs, despite tests revealing there was no *E. coli* in their urine. They also collected biopsies from three women who had never knowingly had a UTI. No transgender people were included in the study.

Those with persistent UTI symptoms had overgrowths of nerve cells in their bladders, compared with the other women. These nerve cells also had higher levels of a peptide called substance p, which causes pain and inflammation.

Tests in mice with recurrent UTIs revealed that treating them with compounds to suppress the production of substances that encourage nerve growth prevented lingering pain (*Science Immunology*, doi.org/mj5r).

The team hopes the results could help with the development of a treatment to prevent ongoing symptoms in people. ▮

Life

Earliest known sex chromosomes evolved in ancient octopuses

Kenna Hughes-Castleberry

DAVID HALL/NATUREPL.COM

A sex chromosome was found in the California two-spot octopus

OCTOPUSES weren't thought to have sex chromosomes, but now they have been found in a species native to the Pacific Ocean. These chromosomes evolved up to 378 million years ago, so are the earliest known example of sex chromosomes and the first evidence of genetic sex determination in cephalopods – a group that includes squid, cuttlefish, octopuses and nautiluses.

"Cephalopod sex determination has been a complete mystery up to this point," says Andrew Kern at the University of Oregon. Researchers had long thought that cephalopod sex was determined by environmental factors, such as temperature. But Kern and his colleagues have found otherwise.

The researchers have been compiling a genetic database for the California two-spot octopus (*Octopus bimaculoides*) to create the first complete genetic profile. They found that female octopuses only have one copy of chromosome 17, also known as the Z chromosome, while they possess two copies of every other chromosome.

"This suggested to us that we may have found a sex chromosome in our female that would be inherited," says Kern. To confirm this, he and his colleagues compared the chromosomes of several California two-spot octopuses and found that the males have two Z chromosomes while the females have a ZO pair.

"Cephalopod sex determination has been a complete mystery up to this point"

The researchers compared the data with the genomes of other cephalopods, including other octopus species, three squid species and one nautilus species. They saw the same ZZ/ZO sex chromosomes in the East Asian common octopus (*Octopus sinensis*) and the Hawaiian bobtail squid (*Euprymna scolopes*), suggesting the animals have similar evolutionary patterns.

But there were differences in the genome of the chambered nautilus (*Nautilus pompilius*), which were useful for estimating how long ago the octopus sex chromosomes first evolved.

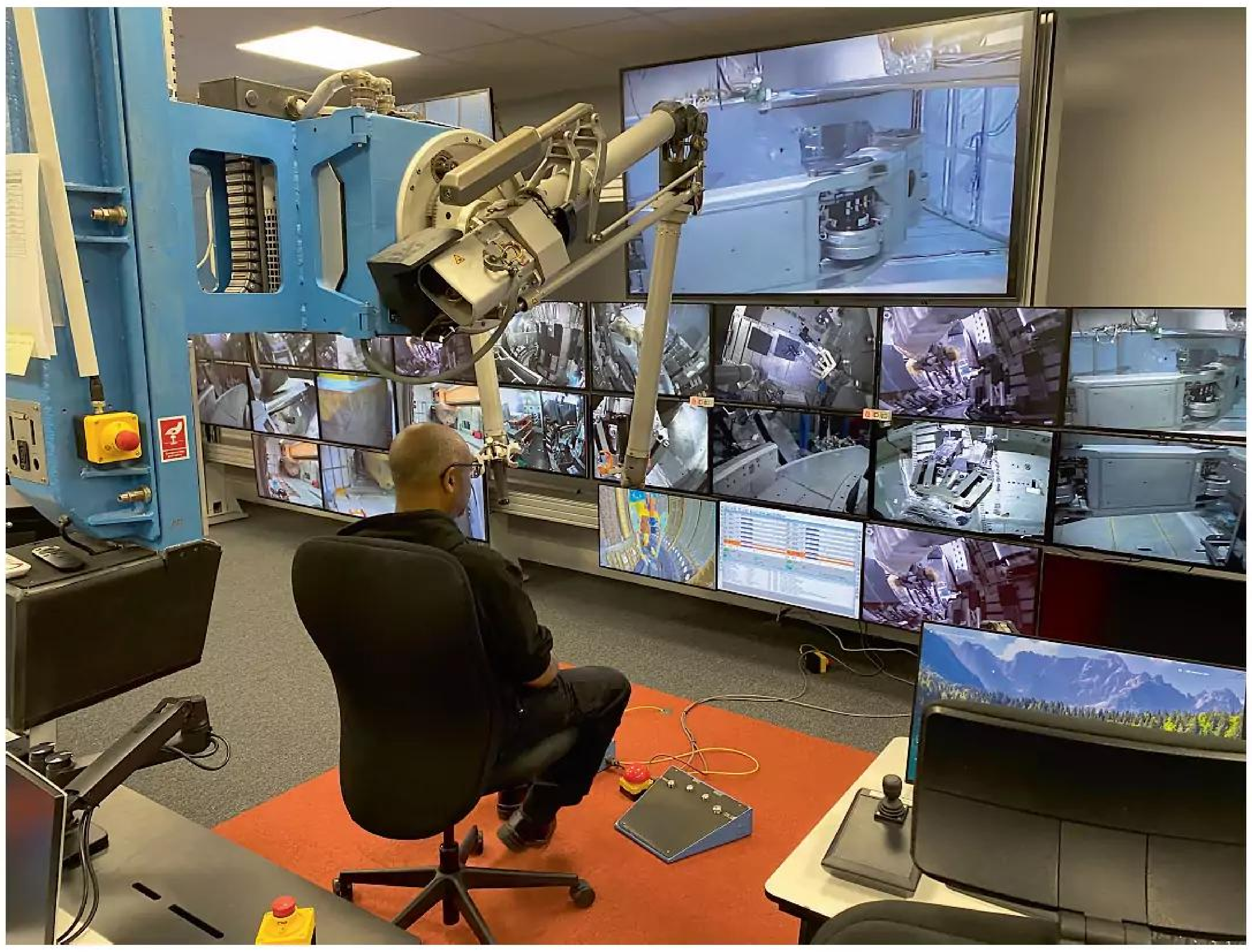
"Incredibly, both the octopus and the squid had the same pattern that we observed," says Kern. But the nautilus genome didn't. The nautilus diverged from other so-called soft-bodied cephalopods between about 455 million and 378 million years ago, which suggests that the sex chromosomes found in the California two-spot octopus originated after that, says Kern. This would make the Z chromosome's molecular age between about 378 million and 339 million years old (bioRxiv, doi.org/mj7r).

Daniel Winston Bellott at the Whitehead Institute in Massachusetts says we have evidence from nematodes of older sex-linked genes or regions of the genome related to determining sex. But Kern notes that these aren't entire chromosomes.

"By knowing which octopuses are biologically male versus female very early in life, we can begin to understand very important questions," says Christine Huffard at the Monterey Bay Aquarium Research Institute, California. "For example, in some populations males far outnumber females, and this skew strongly influences their mating behaviour and social interactions. Now, we'll be able to tell when that difference originates, and if not in the egg stage, then how it develops over time." ▮

Field notes **JET nuclear fusion reactor, Oxfordshire, UK**

How do you recycle a nuclear fusion reactor? In a world-first recycling attempt, engineers are hoping to learn key lessons to enhance future nuclear fusion projects, finds Matthew Sparkes



MATTHEW SPARKES

Inside the JET control room, where robotic arms are manipulated

THE JET nuclear fusion reactor in Oxfordshire, UK, set many records over its 40 years of operation, advancing our understanding of how to spark and contain reactions of the type normally only found in the heart of a star. Although it has now reached the end of its life, it will break records once more as the team behind the experiment attempts something that has never been done before: recycling a fusion reactor.

"We want to repurpose the assets as much as possible – there's well over a billion's worth of equipment here – [and] use it again, as much as we can, for UK science," says Ian Chapman, the head of the UK Atomic Energy Authority (UKAEA). "We're going to learn a whole load just going through that process."

No other tokamak reactor – the doughnut-shaped fusion device that is one of a clutch of designs being worked on around the world – has ever been carefully deconstructed in this way. The closest attempt was the US Tokamak Fusion Test Reactor, which was simply disposed of like nuclear waste at the end of its life – they "chopped it up, grouted it, buried it", says Chapman.

105,929

Number of ignition attempts in the JET fusion reactor

Standing in the cavernous room that houses the defunct reactor, I can hear it still emitting a loud hum, but after 105,929 attempts at ignition, this machine will never fire again. Instead, the noises are from the dense layers of infrastructure that obscure the reactor's plasma vessel, cooling its components and keeping fresh air passing through it, scrubbing any radioactive contaminants produced by the fusion reactions before the air is released to the room outside.

Dozens of researchers have climbed within JET's 100-cubic-metre vessel over the decades, having to squeeze through a tiny port around 40 centimetres by 80 centimetres – something that I am told takes a certain technique of twisting the shoulders and isn't a job for the claustrophobic.

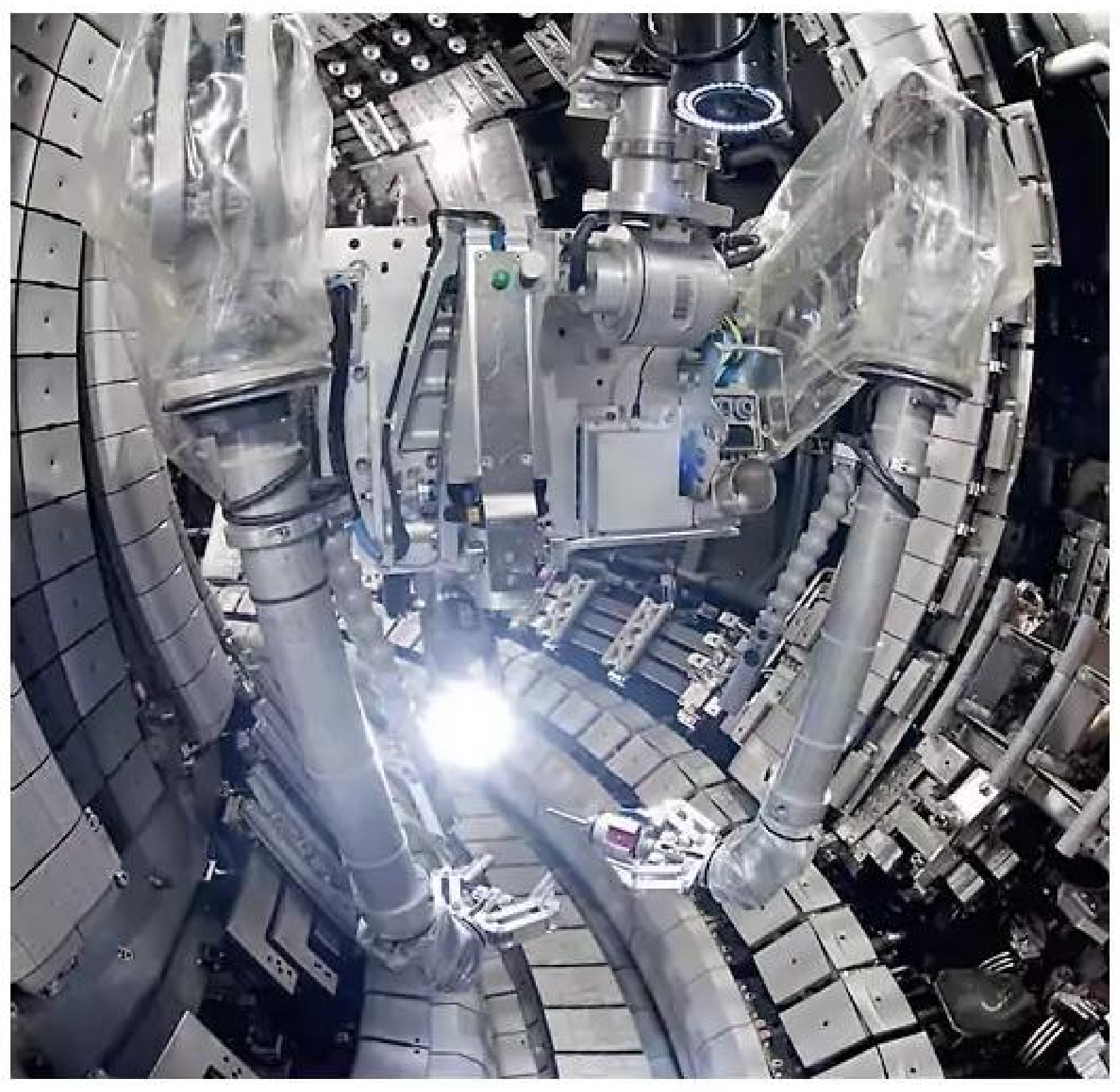
But Gary Hermon, who works on the robotic arms that once maintained JET, says no human will be allowed inside again. That is because the final, record-breaking experiments "turned the power up to 11" and left the interior more contaminated than ever before, he says. "It's become a very hostile environment."

Instead, scientists will have to make do with the robotic arms – which date back to the 1980s and show signs of their age – during decommissioning. They will be operated remotely from a control room, 5 minutes' walk from the reactor itself. This is a safer and more comfortable job, but also a trickier one. The robots have to perform a similar contortion to enter the small port, while wearing a plastic gown to shield them from contamination (see image below).

Despite shutting down, the site will remain a hive of activity. During operation, there were around 600 engineers and scientists working on JET, and during the decommissioning there will still be 200. The rest will stay in fusion research, says Chapman, moving to other projects under UKAEA control.

Current and former JET workers touring the reactor with me have some strange, if scary, stories to tell. Elena Righi, head of Euratom Research at the European Commission, who worked at JET for seven years from 1990, recalls working overnight and hearing a loud bang from inside the reactor. She was certain that she would be fired for damaging the machine, but, in the morning, nothing untoward was found. "This machine was built to outlast us," she says. Another worker recalls the time computer instructions were accidentally run backwards, pushing an experiment far harder than expected, but revealing that the plasma vessel could take it.

Robots like this one will dismantle the JET reactor from the inside



EUROFUSION

Yet JET's time as a useful experiment eventually ran out. As parts of the reactor are removed, they will be inspected for clues as to how they were contaminated, where retrievable fuel is located and how components degraded – all information that will help in the operation and dismantling of future reactors.

Various diagnostic systems, cameras, heating systems and vacuum chambers will be stripped and shipped to other fusion projects. A large flywheel that helped power experiments at JET will go to the National Grid to assist in stabilising the UK's power supply. Other parts will be made available to UK museums.

The final amount of radioactive waste left after decommissioning will fit in just two or three containers, each about the size of a small car. Most of the fuel embedded in components will be reclaimed, packaged up and stored for future experiments, says Chapman. JET's legacy looks set to continue as researchers attempt to harness the awesome potential of nuclear fusion. ▮

Mind

Something from nothing

The absence of predators to worry about may have helped us conceptualise the idea of "zero"

James Woodford

THE human brain may have learned to grasp the figure zero and apply it to our lives by building on a primitive neural pathway used for counting predators. Understanding this could let doctors help people who struggle to understand numbers after a stroke.

Zeros are used in many aspects of society, from astronomy and engineering to accounting and literature. To understand the figure's origin, Benjy Barnett and Steve Fleming at University College London used magnetoencephalography (MEG) to record the magnetic fields produced by 29 people's brains while they completed two tasks.

In the first, people compared whether two consecutive patterns were made up of the same numbers of dots, from 0 to 5. In the second, they saw 10 numbers, also from 0 to 5, each for 250 milliseconds. Half were orange and the rest blue. They then reported which coloured numbers had the highest value.

To compare people's brain activity when they saw a "0" with them seeing other numbers, Barnett and Fleming fed the MEG data into a machine-learning algorithm.

Scientists have long known that there are neurons in the brain that respond specifically to someone seeing a "1" or a "2" and so on until at least "9", says Barnett.

"We showed that the neural activity across different brain areas in response to '0' was most similar to the activity underlying '1'," he says. "What's more, the neural activity for '0' became less similar to brain patterns evoked by other numbers as these other numbers got larger, suggesting it has a place at the beginning of the neural number line – next to '1', and two less than '2', and so on."

The pair also looked for any similarities between the brain's response to "0" and a blank screen, finding that both activated the same activity pattern. This suggests that our understanding of the concept of zeros may have evolved from the perception of absences (bioRxiv, doi.org/mj5b).

> "'No, I haven't seen anything' might be the precursor to the number zero in the brain"

"If I'm an antelope on the savannah and I perform a quick visual scan to check if I can see any predators, the brain activity that leads me to decide 'no, I haven't seen anything' might be the precursor to the number zero in the brain," says Barnett. Humans and other animals seem to have the ability to understand absence, but people have built on this to utilise zeros, he says.

A previous study of more than 650 people who had had a stroke found that about 15 per cent were unable to accurately process numbers containing zeros in the following weeks.

"Our results may well contribute to a better understanding of this phenomenon and help inform potential treatments," says Barnett.

Jorge Morales at Northeastern University in Boston says that despite the importance of zero in mathematics and various cultures, this study suggests that the concept originates from the ability to notice absences, which we probably share with other animals. ■

Food science

Miso paste made in space opens new food frontier

AN EXPERIMENT carried out on the International Space Station (ISS) has produced what is thought to be the first deliberate fermentation of food conducted off Earth.

Miso is a paste from Japan made from fermented soya beans and rich in umami flavours. To see how it would develop in the increased radiation and microgravity of space, Joshua Evans at the Technical University of Denmark and his colleagues prepared a small container of cooked soya beans. They added koji – a fermented rice product containing the *Aspergillus oryzae* fungus – and salt. This fungus and a variety of bacteria transform the soya beans into miso.

MAGGIE COBLENTZ

Three pots of miso stand ready for sampling after fermentation

The researchers split the miso mix into three portions and froze them until the start of the 30-day experiment. They then sent one portion to the ISS on a SpaceX rocket in March 2020. The other two were fermented in Cambridge, Massachusetts, and Copenhagen, Denmark.

While on the ISS, the miso was kept in a box with sensors that measured temperature, pressure, light, radiation and relative humidity.

Evans and his colleagues tasted the miso themselves. "These misos looked like miso, smelled like miso and the recipe was a tried and tested one, so we didn't feel much cause for concern," says Evans.

The space miso tasted different from the two earthbound samples, he says. "It was more pungent than the other two, with more nutty and roasted aromas and more umami taste. It was also darker." These differences suggest fermentation was faster in space, he says (bioRxiv, doi.org/mj43).

"It is interesting to consider the possibilities of future astronauts on long missions growing their own food in circular systems that recycle nutrients and water, and how fermentation might help improve its nutrition and taste," says Ben Schulz at the University of Queensland, Australia. ■ JW

Analysis **Personalised medicine**

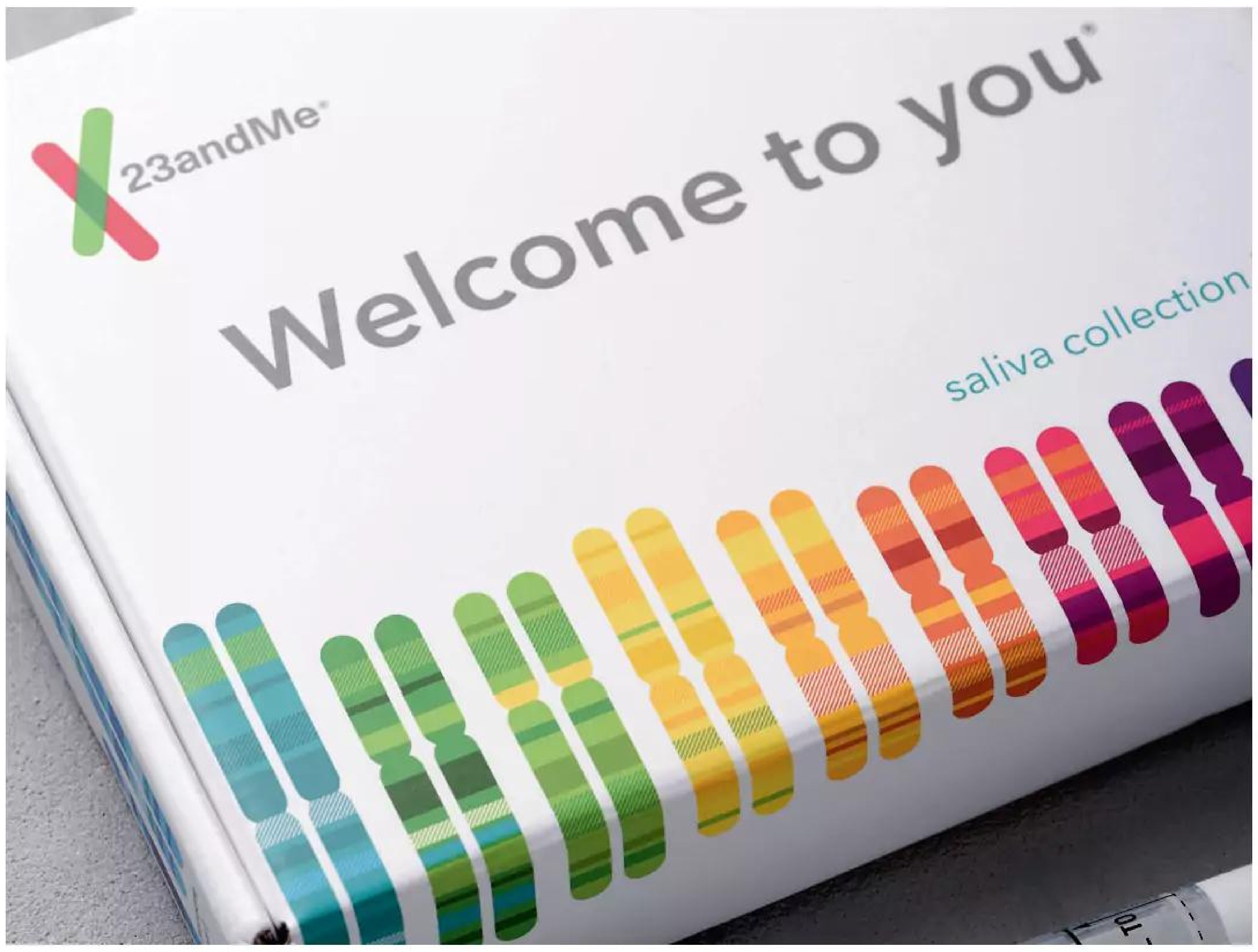
Does 23andMe's decline show genetic-based medicine has been overhyped?

For years, personal genetics firm 23andMe has seemed to represent the future of healthcare, but now it is in dire financial straits. What went wrong, asks **Clare Wilson**

UNTIL recently, the US firm 23andMe seemed to symbolise the promise of a new, futuristic kind of medicine, precision-guided for individuals by their genetic data.

But earlier this year, it emerged that the company is in dire financial straits, with its value having fallen by 96 per cent since its 2021 high. Does this mean the goal of genetically based medicine has been overhyped or are other factors at play?

23andMe – named after the 23 pairs of chromosomes that constitute human DNA – was founded in 2006, making it one of the first companies to aim genetic tests squarely at the public. The idea was to exploit the burgeoning potential of genetics, along with people's appetite for learning about themselves, like finding out their ancestry or if they have a raised risk of developing certain medical conditions.



NEVODKA/ALAMY

23andMe's genetic testing involves people sending off a saliva sample

Spit parties

In 2008, the company's DNA saliva test was named "Invention of the Year" by *Time* magazine and media outlets enthusiastically covered its "spit parties", where people collected saliva samples en masse.

But while some people have undoubtedly learned useful health information from genetic testing, any population-wide benefits always seem to be just around the corner, held back by our limited understanding of the human genome. "When the Human Genome Project started, they had a very clear vision of incorporating genomics into clinical practice," says Kian Sadeghi at genetic testing firm Nucleus in New York. "That obviously has not happened."

23andMe hit problems in 2013 when the US Food and Drug Administration said that its tests intended to indicate a person's risk of various medical conditions weren't sufficiently supported by science. The firm had to pull all its health-related tests from the US market.

2008

When *Time* named 23andMe's DNA test "Invention of the Year"

2013

When 23andMe pulled tests from the US after a government ruling

2021

The firm's stock has fallen in value by 96 per cent since this year

After a two-year hiatus, 23andMe relaunched its tests for a more limited number of conditions. However, for most of the genes being tested, either the disease-causing variant is rare or, in the case of Alzheimer's disease, it gives people no useful additional information because there is little they can do to lower their risk other than following general healthy lifestyle advice.

Sadly, the initial hopes that being able to decode the human genome would lead to powerful disease-prevention strategies for large subsets of people haven't yet been borne out. Most common conditions, such as heart disease, diabetes and depression, are influenced by hundreds of gene variants, each with small effects, so targeting just one would have little impact. This means that when it comes to developing new treatments, there are usually no quick fixes.

Recently, however, there has been progress, with it becoming possible to measure many such variants and calculate someone's overall genetic risk for certain conditions, known as a polygenic risk score, which 23andMe began offering for multiple conditions in 2021. But any resulting prevention measures are still similar to general health advice for everyone.

One of 23andMe's other core goals was to utilise its wealth of genetic data to discover new medicines. That plan is still in its infancy, having so far yielded two drugs in early-stage clinical trials. This reflects the fact that drug discovery is a long-term and expensive business, says Peter Donnelly at Genomics, a UK genetic analysis firm.

Despite 23andMe's financial woes, publicly funded genetic research is expanding, including huge and ethnically diverse biobanks being built in the UK and the US. Projects such as these are producing polygenic risk scores for people on an unprecedented scale.

Risk assessment

The hope is that, in time, doctors will use polygenic risk scores to guide screening and treatment decisions for more people, says Donnelly. "There are many things we do in health systems where we use risk for deciding who to put into prevention or treatment programmes, and all they use is age," he says. "We can be much more sophisticated about risk than that and genetics is a big part of risk."

A 23andMe spokesperson says: "Many 23andMe customers have discovered genetic risks for disease, taken those results to their doctors and have implemented medical interventions to help prevent or better treat disease… Learning of genetic risks for the diseases in our [polygenic risk score] reports could lead to earlier screening and detection."

Regardless of whether one company can make genetic testing profitable, it may be premature to write off the entire field. But those eager for the new age of personalised medicine may have to wait a little longer – as ever, it is "just around the corner". ▮

Music

Pythagoras was wrong about music

The idea that musical notes sound best in certain mathematical combinations doesn't seem true

Chris Stokel-Walker

AN ANCIENT Greek belief about the most pleasing combinations of musical notes – often attributed to the philosopher Pythagoras – doesn't actually seem to reflect the way people around the world appreciate harmony. Instead, Pythagoras's mathematical arguments may merely have been taken as fact and used to assert the superiority of Western culture.

According to legend, Pythagoras found that the ringing sounds of two blacksmith's hammers were most pleasant, or "consonant", when the ratio between the size of their tools involved two integers, or whole numbers, such as 3:2.

The philosopher's belief that listeners prefer music played in perfect mathematical ratios was so influential that it has shaped how Western musicians play chords. "Consonance is a really important concept in Western music, in particular for telling us how we build harmonies," says Peter Harrison at the University of Cambridge.

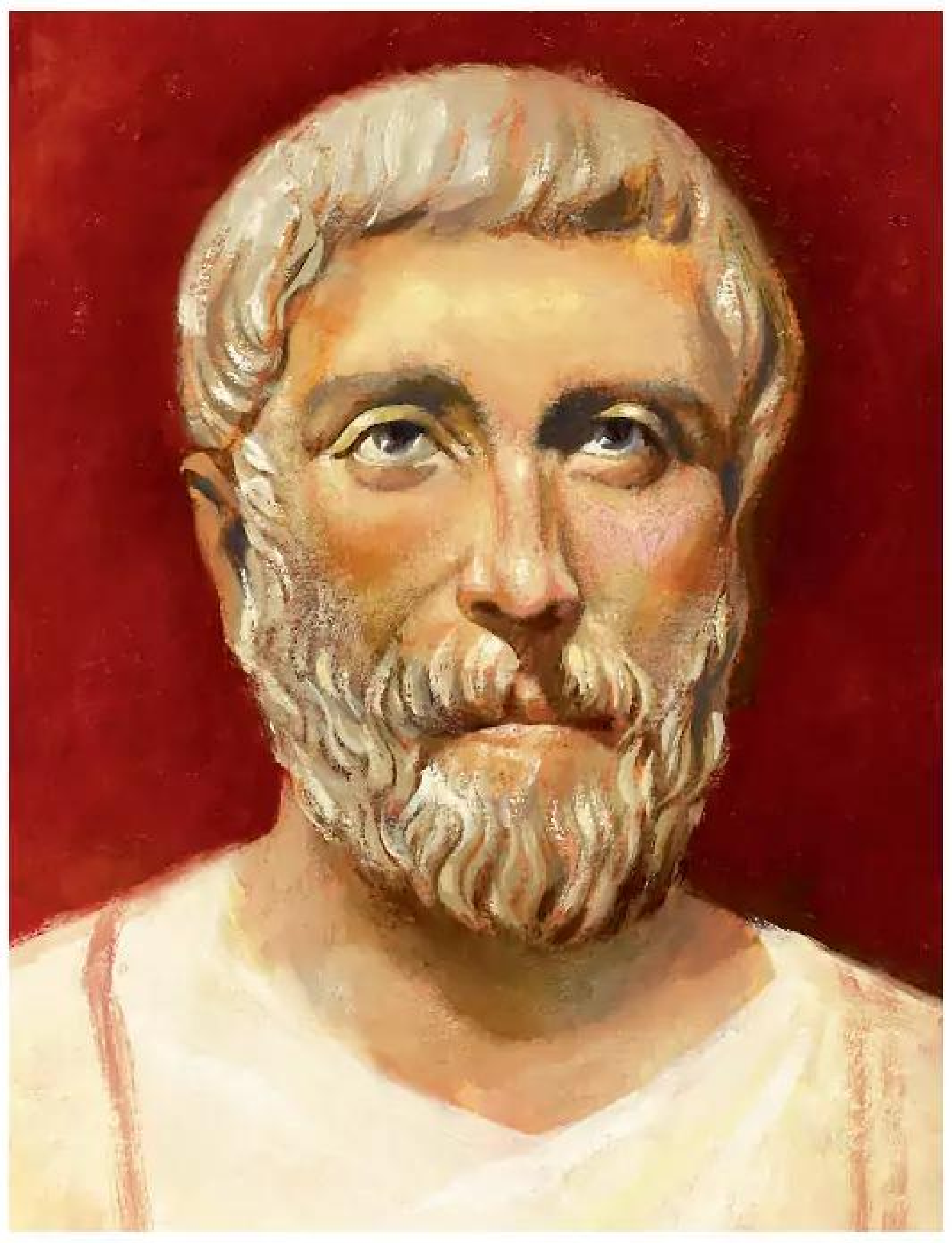
But when Harrison and his colleagues surveyed 4272 people in the UK and South Korea about their perceptions of music, their findings flew in the face of this ancient idea. In one experiment, participants were played musical chords and asked to rate how pleasant they seemed. Listeners slightly preferred sounds with an imperfect ratio.

Another experiment discovered little difference in appeal between the sounds made by instruments from around the world, including the bonang, an Indonesian gong chime, which produces harmonies that can't be replicated on a Western piano (*Nature Communications*, doi.org/mjq3).

Although instruments like the bonang have traditionally been referred to as inharmonic in Western music culture, study participants appreciated the sounds of the instrument and others like it. "If you use non-Western instruments, you start preferring different harmonies," says Harrison.

"It's fascinating that music can be so universal yet so diverse at the same time," says Patrick Savage at the University of Auckland, New Zealand. He says that the current study also contradicts previous research he did with some of the same authors, which found that rhythms based on integer ratios are surprisingly universal.

Greek philosopher Pythagoras has influenced Western music for millennia



PRISMA ARCHIVO/ALAMY

Michelle Phillips at the Royal Northern College of Music in Manchester, UK, points out that the dominance of Pythagorean tunings, as they are known, has been in question for some time. "Research has been hinting at this for 30 to 40 years, as music psychology has grown as a discipline," she says. "Over the last 15ish years, people have undertaken more work on music in the whole world, and we now know much more about non-Western pitch perception, which shows us even more clearly how complex perception of harmony is."

Harrison says the findings tell us that Pythagoras was wrong about music and that music theory has been too focused on the belief that Western views are held worldwide. "The idea that simple integer ratios are superior could be framed as an example of mathematical justification for why we've got it right over here," he says. "What our studies are showing is that, actually, this is not an inviolable law. It's something that depends very much on the way in which you're playing music." ▮

Physics

Magnetic particles turn water drops into acrobats

PUTTING tiny magnetic particles inside ordinary water droplets can turn them into liquid acrobats that can climb steps, leap over obstacles and jump-start chemical reactions. This level of control could be useful for medicine or in research.

Shilin Huang at Sun Yat-sen University in China and his colleagues made a surface with tiny grooves and covered it in a varnish that is superhydrophobic, or nearly impossible to wet. They knew that water droplets sitting on top of such grooves could spontaneously jump up, a phenomenon caused by the pressure difference between a droplet's bottom, which is deformed by the small channel, and its rounder and less restrained top.

To create this pressure difference on demand, the researchers put a magnetic particle into each droplet and placed an electromagnet underneath the grooves. When they turned on the electromagnet, it pulled the particle – and some of the droplet – into the groove. When they switched it off, the droplet's shape rebounded and it flew upwards as if from a slingshot.

"When they switched the electromagnet off, the droplet flew upwards as if from a slingshot"

With this technique, Huang and his colleagues made liquid droplets hop up millimetre-scale stairs and over miniature obstacles. They also steered a droplet into a space between two wires, connecting a circuit and lighting a light bulb.

In one experiment, the researchers made a droplet jump into and mix with a liquid chemical sample under a microscope lens, enabling them to watch the resulting chemical reaction. In another, they made two droplets mix with a third in a closed box, remotely starting a reaction that would have been ruined if they had needed to open the box and let air in (*ACS Nano*, doi.org/mjqz).

Such precise control could be useful for drug delivery, says Huang. He also hopes it could advance "lab-on-a-chip" technologies, efforts to miniaturise complex biochemistry experiments. He proposes "lab-on-stacked-chips", where droplets vertically jump between levels to allow many reactions to happen in parallel. ▮

Karmela Padavic-Callaghan

Space

Promising exoplanet may not be habitable ocean world after all

Jonathan O'Callaghan

A DISTANT planet once touted as a potential location to look for alien life is actually likely to be inhospitable.

In 2015, astronomers discovered a planet 110 light years away called K2-18b, which later analysis estimated to be a super-Earth or mini-Neptune about eight times the mass of our world.

Researchers in 2019 then found evidence for water vapour on the planet. Since K2-18b is thought to be in the habitable zone of its star – the region in which water can exist as a liquid on the surface of a planet – that led to suggestions it might be an ocean world.

Prospects were further buoyed by research in 2023 that found evidence of dimethyl sulphide, a molecule that, on Earth, is only produced by life, particularly marine phytoplankton.

But now, Nicholas Wogan at the NASA Ames Research Center in California and his colleagues have re-analysed the planet using data from the James Webb Space Telescope (JWST). They say an abundance of methane and carbon dioxide seen by JWST points to the planet being a gas-rich mini-Neptune with no surface, rather than a habitable super-Earth with an ocean and sea floor, because such gases would be broken down by a process called photolysis if it were an ocean or "hycean" world (arXiv, doi.org/mjns).

The researchers write that there are two options, with the planet being either a "Hycean world inhabited by methanogenic life" – that which produces methane – "or a mini-Neptune with no defined surface. The latter case is less complex and requires fewer assumptions." In both cases, the evidence for the dimethyl sulphide may simply be a false signal.

"Overall, we favour the mini-Neptune explanation," they write.

Health

Light flashes may slow Alzheimer's by making the brain remove toxins

Clare Wilson

A NEW explanation has emerged for why an experimental treatment for Alzheimer's disease involving sounds and flickering lights may help slow cognitive decline. The frequencies involved seem to ramp up the brain's waste disposal networks, which boosts the clearance of beta-amyloid and other toxic proteins that contribute to memory and concentration problems.

"Once we understand the mechanism, we can probably figure out how to further optimise this whole concept and improve the efficacy," says Li-Huei Tsai at the Massachusetts Institute of Technology.

The treatment involves exposing people to lights flickering at a frequency of 40 times a second, or 40 hertz, and a low-pitched sound, also at 40 Hz. Typically, the stimulation is given for an hour a day.

Key to the novel approach is that large networks of brain cells naturally fire in sync with each other at different frequencies – known as brainwaves. Brainwaves of around 40 Hz are often seen when people are concentrating and when they are forming or accessing memories.

As it was known that visual or auditory stimulation at a certain frequency can boost brainwaves at that same frequency, in 2016, Tsai's team investigated if stimulation at 40 Hz might boost cognitive abilities in people with Alzheimer's.

40 Hz

Frequency of bursts of light and sound used to treat Alzheimer's

Their group and others showed that this lowered amyloid build-up in mice with a version of Alzheimer's and had cognitive benefits in small trials in people with the condition. But it wasn't clear how the treatment works, with one idea being that it boosts the function of the brain's immune cells.

Now, it seems the lights and sound work by enhancing the function of the brain's drainage network, also known as the glymphatic system.

In the latest work, Tsai's team did experiments to study the treatment's mechanism in mice that had been genetically altered so that they usually develop a build-up of amyloid as they get older and have worse memories than typical mice.

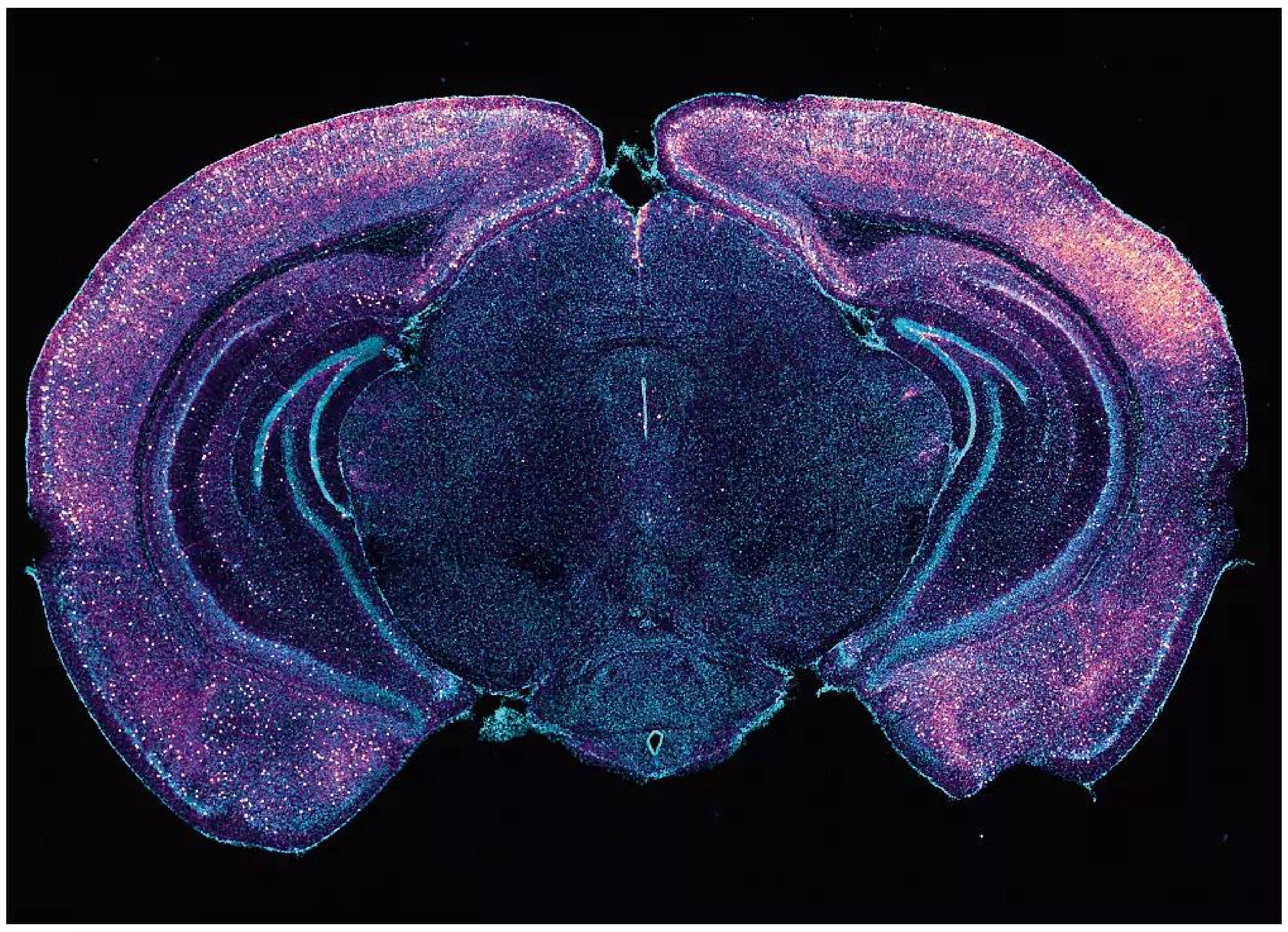
As expected, when the animals were exposed to the light and sounds, they had less amyloid. The new finding was that during the treatment, they had a greater amount of cerebrospinal fluid entering the brain and more waste fluid leaving it through the glymphatic vessels (*Nature*, doi.org/mjjs).

This seemed to be happening because nearby blood vessels were pulsating more, which could help push the glymphatic fluid through its vessels, and because of more water flowing into the glymphatic system.

The team also found that the activity of brain cells known as interneurons seemed to be triggering the increased glymphatic flow by releasing a molecule called vasoactive intestinal peptide. When the team chemically blocked this molecule's production, the treatment no longer boosted amyloid clearance.

Maiken Nedergaard at the University of Rochester in New York, who helped discover the glymphatic system, says the finding fits with what we know about the system. "The brain, blood and cerebrospinal fluid are all contained within the skull. If the blood volume expands, the volume of the cerebrospinal fluid has to move since brain tissue is not compressible." A better understanding of toxin clearance in the brain could help us unlock its therapeutic potential, she says.

Highlighted neurons in a mouse brain that seem to boost toxin clearance



TSAI LABORATORY/MIT PICOWER INSTITUTE

Technology

AI maths skills get a *Star Trek* boost

Chatbots get better at sums if you ask them to answer as if they were a Starfleet captain

Chris Stokel-Walker

ALBUM/ALAMY

Star Trek: Strange New Worlds **can play a role in the AI universe**

INSTRUCTING an AI chatbot to answer questions as if it were in the sci-fi franchise *Star Trek* seems to improve its mathematical ability, but no one is sure why.

The output of chatbots like ChatGPT can be improved by prompting the AI to adopt a certain persona. To discover the most effective prompts, Rick Battle and Teja Gollapudi at software firm VMware in California turned to the large language models (LLMs) that power the chatbots.

They used them to fine-tune human-created prompts and then rated their effectiveness at solving a set of US grade-school mathematics questions called the GSM8K benchmark.

The researchers gave 60 prompts to three LLMs: one developed by French firm Mistral, and two versions of Llama2, made by Meta. The AIs were then instructed to tweak the wording of the messages to make them more effective.

For example, from an initial prompt of "You are an expert mathematician. Solve the following math problem. Take a deep breath and think carefully," the AI-improved prompt might add requirements to define any assumptions, or to flag any loopholes used.

The resulting prompts were fed back into the AIs in an effort to tackle the GSM8K questions, which require simple arithmetic to solve, but take between two and eight steps to complete.

In nearly all instances, the AI models produced prompts that generated more correct answers to the questions than human-created prompts. "In my opinion, nobody should ever attempt to hand-write a prompt again," says Battle. "Let the model do it for you."

However, entrusting a chatbot to write prompts can result in unusual ideas. The highest-scoring prompt generated by the Llama2-70B model, for instance, asked the chatbot to adopt the persona of the captain of a *Star Trek* spaceship, jotting down answers in its "captain's log" (arXiv, doi.org/mjjb).

Why the AI produced such unusual prompts is "the $64 million question", says Battle. "To a certain extent, the answer is 'I don't care, just give the model what it wants'." However, he thinks it is a product of the data used for training, perhaps with *Star Trek* content appearing more often with correct information. "There's a lot of *Star Trek* references on the internet," he says.

"We won't ever know why [these models] do what they do because ultimately they are a melange of weights and probabilities and at the end a result is spat out," says Catherine Flick at Staffordshire University, UK.

Despite the fact that the *Star Trek*-themed prompt was the most successful, Flick says you shouldn't be addressing any chatbots as "commander" any time soon. "The model is not a Trekkie," she says. "It doesn't 'understand' anything better or worse when preloaded with the prompt, it just accesses a different set of weights and probabilities." ▮

Animal behaviour

Follow a dog for 15 minutes to make a new friend

SHUTTERSTOCK/JUS_OL

Pet dogs often keep close to their owners, but that is rarely the case with strangers

MANY dogs are hesitant to warm up to strangers – but now there might be an easy way to make friends, just by following the animals.

"It's creating familiarity between the dog and the human, without having to touch or use toys or food, or even make eye contact," says Angélique Lamontagne at Aix-Marseille University in France.

Lamontagne and her colleagues fitted 32 pet dogs with a camera and a GPS device on a harness. They let each dog wander in an open field, one at a time, for 15 minutes while their owner stood nearby.

The dogs were then split into two groups. In the first, a researcher that the dogs hadn't seen before followed each animal wherever it went for 15 minutes, staying side-by-side less than a metre away. For the other group, they stayed "unsynchronised", keeping their distance and moving, stopping and starting at different rates. In all cases, the researcher avoided looking at or talking to the dogs.

After this exercise, the researcher called the dog, then looked at it and spoke to it for 10 seconds. Straight afterwards, they turned and walked away, without looking at or talking to the dog.

Dogs that had been followed for the first 15 minutes stayed much closer to the researcher than those that hadn't (*Applied Animal Behaviour Science*, doi.org/mjjc).

This suggests synchronisation helps build the relationship between human and dog, says team member Florence Gaunet, also at Aix-Marseille University. That could be because many mammals mirror the movements – like yawning or getting up – of others in their social group. ▮

Christa Lesté-Lasserre

Analysis Coronavirus

Does even a mild case of covid-19 affect your cognitive skills?

A big study suggests that people who catch the disease do worse on cognitive tests, but the findings are far from definitive, says **Michael Le Page**

DO MOST of us have slightly diminished brainpower as a result of getting covid-19? That is the implication of the largest study on this so far, involving more than 100,000 people, but its findings raise more questions than they answer.

A team in the UK invited 800,000 people in the country to take part in research on the cognitive effects of covid-19. Of those, around 113,000 completed a series of online tests at some point between August and December 2022, evaluating their memory, reasoning and attention.

After adjusting for factors such as age, the researchers compared the scores of the 67,000 people who were confirmed to have had covid-19 with the 46,000 who hadn't had a definite infection.

As expected, they found that people who had symptoms for more than 12 weeks – which is the usual definition of long covid – or had gone to hospital for treatment did worse in the cognitive tests on average. This is in line with many previous studies showing that severe covid-19 can affect cognitive skills.

Brain shrinkage

However, to the surprise of the researchers, even those whose symptoms lasted less than 12 weeks and who didn't need hospital treatment did worse on average than the no-confirmed-infection group (*New England Journal of Medicine*, doi.org/mjhz).

"I was not expecting that we would see any significant impact in the short-duration groups," says team member Adam Hampshire at Imperial College London.

That said, some smaller studies have suggested that even mild cases of covid-19 can affect the brain. One found that parts of the brain shrink, for instance.

113,000

This many people joined a study of covid-19's cognitive effect

67,000

Number of those who had a confirmed coronavirus infection

3

Impact of having covid-19 is like losing this many IQ points

Covid-19 can cause changes to the brain that show up in MRI scans

GO NAKAMURA/GETTY IMAGES

Brain fog has been a widely reported symptom of covid-19, with the latest study finding measurable differences in the memory and executive abilities, such as spatial planning, of people who reported having it, says Hampshire.

The good news is the overall difference between those who had or didn't have covid-19 was small – 0.2 standard deviations on average. In an IQ test, a difference of this size would equate to 3 points, says team member Paul Elliott, also at Imperial College.

He doesn't think that anyone who experiences the effect on this scale will notice it, although this is just the average and some will be hit harder.

Elliott also points out the biggest differences were found in people who got infected early on in the pandemic. One reason for this is that many of those who got infected later were protected by vaccination, with people who had two or more doses scoring higher on the cognitive tests.

It is also possible that later variants of the virus had less effect on cognitive abilities, but the study cannot say if this is so. "We can't disentangle these things," says Elliott.

Does this mean that if you get covid-19 now, your cognitive abilities are less likely to be affected? Maybe, but it is also possible the protective effects of vaccination are declining now that many people are no longer getting boosters.

Another big question is whether people's cognitive abilities can recover over time or if the effect is permanent. And if it is permanent, will our abilities decline a bit every time we get covid-19? "We don't know what the long-term effects will be," says Elliott.

Lasting effect?

Most people with confirmed covid-19 in the research were tested more than 12 weeks after infection, so the effect can certainly last many weeks. The team hopes to do follow-up studies of the participants so see if there is any cognitive recovery.

The researchers are also planning to examine 10,000 of the participants further, which might help reveal how the virus can affect our cognitive abilities. Hampshire thinks more than one mechanism is probably involved.

The big weakness of the latest study is people only did the tests once. What is really needed is an investigation where people are tested before getting covid-19 and afterwards at regular intervals to see how their cognitive abilities change.

But it is, of course, no longer possible to do such a study because pretty much everyone on the planet has already been exposed to the virus that causes covid-19, meaning we may never know for sure exactly what it has done to our minds. ■

Cosmetics

Hyaluronic acid skin benefits oversold

THE popular skincare ingredient hyaluronic acid doesn't hold 1000 times its weight in water, despite frequent marketing claims.

The ingredient is a humectant, a substance that attracts moisture. Applied topically, it can improve skin hydration, enhance elasticity and reduce wrinkle depth.

Each hyaluronic acid unit has 12 atoms capable of binding to water via hydrogen bonds. If hyaluronic acid could bind to water 1000 times its weight, each unit would have to hold around 22,000 water molecules.

Scott Borchers and Michael Pirrung, both at the University of California, Riverside, have found that each atom can only bind to three water molecules, making a maximum of 36 water molecules per unit (ChemRxiv, doi.org/mjps).
Larissa Fedunik

Technology

AI designs bespoke 3D-printed eyes

PROSTHETIC eyes that are designed by artificial intelligence and 3D printed require 80 per cent less time from human specialists than conventional manufacturing methods do.

Making a prosthetic usually takes about 8 hours, but now, Johann Reinhard at the Fraunhofer Institute for Computer Graphics Research in Darmstadt, Germany, and his colleagues have developed a method in which an optical coherence tomography scanner uses light to create a 3D model of a person's missing eye, so the back of the prosthetic can be designed for a close fit (*Nature Communications*, doi.org/mjpr).

An AI model then makes a design that is 3D printed and can just be polished and adjusted by an ocularist, which takes 20 per cent as long as the whole design process usually takes. **Matthew Sparkes**

BANJONGSEAL324/GETTY IMAGES

Chemistry

Greener way to dye denim could cut its climate impact

A TECHNIQUE for dyeing denim using a chemical that turns blue in sunlight could slash the environmental impact of jeans manufacturing.

Blue denim is dyed with indigo, a compound once extracted from plants but usually synthesised today. Chemicals such as sodium dithionite are needed to make indigo soluble in water so that it can be used for dyeing. These chemicals produce toxic fumes that can harm textile workers and also lead to toxic pollution in waste water.

Now, Ditte Hededam Welner at the Technical University of Denmark and her colleagues have developed a process that instead uses a natural precursor to indigo called indican.

"It is soluble, so you can just basically dip your textile in it," says Hededam Welner. "That's why it became such an appealing solution to this because you can simply omit so many of the harsh chemicals."

There is one key disadvantage: indican is colourless, so must be converted into indigo after it has been applied to a material. One way to do this is just to leave it in sunlight for several hours (*Nature Communications*, doi.org/mjpq).

"Over time, as you wear a pair of indican-soaked jeans out in the sunlight, then it will turn blue," says Hededam Welner. "I think that's a gimmick, right? You could do that."

The team found you could also prompt the colour change using electrical lights, cutting the carbon dioxide emissions, land use, water consumption and ozone depletion effects of dyeing by 73 per cent compared with using indigo, according to a European Commission metric. Using enzymes from plants to do this led to a reduction of 92 per cent. MS

Really brief

SHUTTERSTOCK/MARINAFILL

Source of orange flavour is unpeeled

Chemical analysis has revealed 26 compounds responsible for the distinctive flavour of oranges. Seven of the compounds are chemicals called esters, which seem to be the key to distinguishing the taste of oranges and mandarins (*Science Advances*, doi.org/mjpt).

Boil water to get rid of microplastics

Boiling tap water for 5 minutes before use can remove at least 80 per cent of the tiny plastic particles it contains. The particles' impact on health is still being studied, but researchers suspect they are damaging (*Environmental Science & Technology Letters*, doi.org/mjpv).

1 in 8 people have obesity globally

More than a billion people worldwide – or roughly 1 in 8 – have obesity, making it the most common form of malnutrition in nearly every country. The data comes from an analysis of more than 3600 studies from the past 35 years including almost 230 million people across 197 countries (*The Lancet*, doi.org/mjqb).

30 YEARS OF FACTS & FUN

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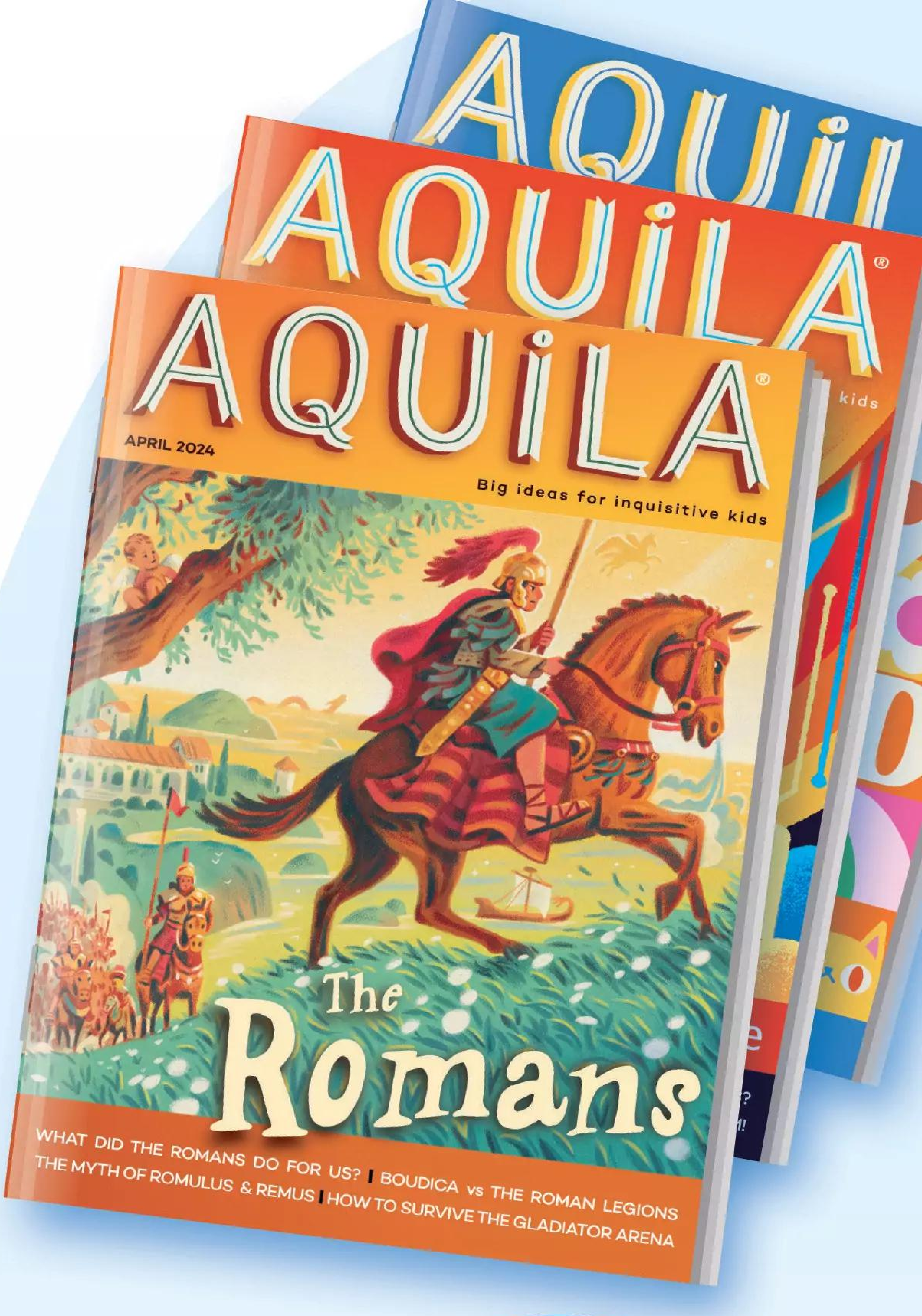
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The columnist
Chanda Prescod-Weinstein on proton decay p22

Aperture
Finalists in Sony's World Photography Awards p24

Culture
A new book explores how climate shapes life and vice versa p28

Culture
Dune: Part Two ignores the weird and plays it too safe p29

Letters
Maybe blue eyes are both useful and alluring p31

Comment

Mind your manners

Living in close proximity to strangers requires shared social norms, but the concept of civility can be used to divide us, says **Kirsty Sedgman**

THIS isn't just any election year. With half the world set to participate in democratic votes, 2024 is being called *the* election year.

As disagreements around issues such as immigration and climate change come to a head, societal schisms are expected to widen even further. But there is one shared ideal that still unites many people: the concept of civility.

In September 2023, a poll found that while US voters are increasingly pessimistic about rising levels of political division, they tend to believe very strongly in norms of manners and respect. Ninety-four per cent agreed that "respect for each other is the first step in having a government that works", and 89 per cent agreed that "civility is the language of respect".

ELAINE KNOX

I have studied the sociology of manners for years, and it turns out that manners really do maketh humanity. While many other species engage in cooperative activities, our capacity to share and divide labour among strangers is a "remarkable and uniquely human" phenomenon, writes evolutionary economist Paul Seabright. The ability to place our trust in strangers became possible around 10,000 years ago through the development of shared norms designed to encourage prosocial behaviour and discourage deviance. This is when we moved from isolated groups of hunter-gatherers into complex societies built on mutual cooperation.

However, words like "civility" and "respect" can be a double-edged sword. In Europe, the concept of civility goes back to Erasmus of Rotterdam's 1530 treatise *De Civilitate Morum Puerilium*. A training guide for young noblemen, it encouraged readers to be considerate of the needs of others, offering advice such as to not spit on the floor or stick dirty hands in food. In that sense, manners can be a significant force for good.

But manners have also been used to set up status hierarchies. The word "etiquette" derives from the 1600s, when King Louis XVI of France used *estiquettes* (small cards) around Versailles to advise visitors on the codified rules of behaviour expected in court. Rather than encouraging consideration, manners were a tool for discerning who belonged in certain social spaces.

Historians have since studied the use of "racial etiquette" for regulating behaviour. From Asia to the Americas, colonial oppressors often forced Indigenous communities into humiliating performances of deference.

In the 1930s, Norbert Elias published his sociological epic *The Civilizing Process*. Pointing out that calls for civility and propriety are often most forceful at times of moral conflict, Elias warned of the dangers of confusing manners with morality. A Jewish exile from Nazi Germany, he had seen how easy it can be to mistake the appearance of civilised propriety for actual ethical decency. According to Elias, the Third Reich deliberately utilised displays of dapper uniforms and cultivated mannerisms as cover for acts of unimaginable brutality.

This wasn't the first time. In the American South, a veneer of courtesy provided cover for the racist violence of enslavement and segregation. Scholars such as Brittney C. Cooper have written powerfully of how marginalised people have needed to cultivate images of "respectability" to survive a hostile public sphere.

In calling for civility again today, then, we need to heed Elias's warning and pay attention to when a facade of mannerly propriety is used to bring about immoral ends – injustice, violence and ecocide all rendered tolerable so long as everyone speaks calmly and behaves decorously. With so much at stake in 2024, we need to reject the appearance of respectability in favour of building a genuinely respectful world in which everyone has an equal chance to thrive. ▮

Kirsty Sedgman is the author of *On Being Unreasonable: Why being bad can be a force for good*

Field notes from space-time

Elementary physics

An experiment to study the elusive neutrino particle is also providing the perfect conditions to seek evidence of proton decay, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her most recent book is *The Disordered Cosmos: A journey into dark matter, spacetime, and dreams deferred*

Chanda's week

What I'm reading

Julian Randall's forthcoming memoir The Dead Don't Need Reminding. *It is brilliant.*

What I'm watching

I recently marathoned every episode of The Real Housewives of Potomac, *and it was terrible.*

What I'm working on

I have been thinking a lot about how to convince people that knowing things is valuable.

AT SOME point in our lives, most of us learn that atoms are comprised of three types of particle: neutrons, protons and electrons. Each has distinct properties. The electron and proton have opposite electrical charge from one another, while the neutron lacks an electrical charge entirely. The electron is also an elementary particle – not comprised of any other entities – while the proton and neutron are both composite particles, each made of three quarks (which are themselves elementary).

From a category standpoint, protons and neutrons are baryons, particles that contain an odd number of quarks. One major difference between elementary particles and composites like baryons is that baryons can fall apart into pieces. For example, a free neutron outside an atomic nucleus has a pretty quick decay time of just under 15 minutes. This is essentially real-life alchemy, as it transforms one element into another. This can occur as beta-minus decay, in which a neutron "crumbles" into a proton, an electron and the antimatter counterpart to neutrinos, an antineutrino. Since the neutron has no charge, the particles that are left over must collectively be chargeless. The electron and proton charges cancel, while the antineutrino is also chargeless.

This leads one to wonder what proton decay is like. Interestingly, it remains an open question. In the 1960s, Andrei Sakharov proposed a hypothetical mechanism for this in which the particle would give way to a positron and a pion, a composite particle made of a quark and an antiquark. But, to this day, proton decay has never been observed in the lab, making it the subject of an intense, global scientific search.

One of the sites for this will be the Deep Underground Neutrino Experiment (DUNE), still under construction, but which will eventually fire neutrinos from Fermilab outside Chicago under Earth's surface to the Sanford Underground Research Facility (SURF) in Lead, South Dakota. Its primary goal is to study the elusive neutrino elementary particles, which interact so little with other types of matter that they are fairly difficult to capture.

But it turns out that experimental conditions that are perfect for studying neutrinos in this way are also perfect for seeking out evidence of proton decay. DUNE's detection facilities are both enormous and deep underground, allowing scientists to monitor large numbers of protons in extremely cold liquid argon. Since proton decay – if it occurs at all – must be extremely rare, observing a sizable number of protons (10^{34} to be specific) is the best way to have a chance of seeing anything unusual, and the argon vats contain a lot of protons.

> **"Scientists are able to monitor large numbers of protons in vats of extremely cold liquid argon deep underground"**

Now you are intrigued by DUNE, you have to hear the hard part. It has had some bad press because of cost overruns and construction delays at SURF, which is in a gold mine that closed in 2002. The pit's origins go back to the 1800s, when the first miners problematically colonised parts of the traditional homelands of the Oceti Sakowin (Sioux) tribal nations.

In this context, it is interesting to consider the ways in which, for all its complications, DUNE is also a significant international project, and not only because its users must contend with recognising the historical injustices faced by the land's traditional knowledge holders. With the support of scientists like US-based particle physicists Kétévi Assamagan and Young-Kee Kim, a group of Malagasy students from Madagascar have trained as neutrino physicists and returned home to create the first African DUNE research team at the University of Antananarivo.

There, a growing group that includes Roland Raboanary is working on an important piece of equipment for the DUNE project, the "near" detector. According to former team member Laza Rakotondravohitra, this will help scientists explore neutrinos more accurately and in ways that have never been done before.

As part of the DUNE experiment, neutrinos will be produced at Fermilab and go through the near detector placed underground at that facility. Then, 1300 kilometres away in Lead, another deep detector will capture the neutrinos from Fermilab, looking for changes in them.

Neutrinos are non-trinary: they come in three flavours and randomly oscillate between them as they travel through space. One of DUNE's goals is to study these oscillations by watching how the flavour population statistics change between the start of the journey and the end.

This is where the University of Antananarivo's contribution to the near detector is key. That instrument will scan the particles as they leave Fermilab on their way to Lead, potentially providing insight into the non-trinary nature of neutrinos in the process. ■

This column appears monthly. Up next week: Graham Lawton

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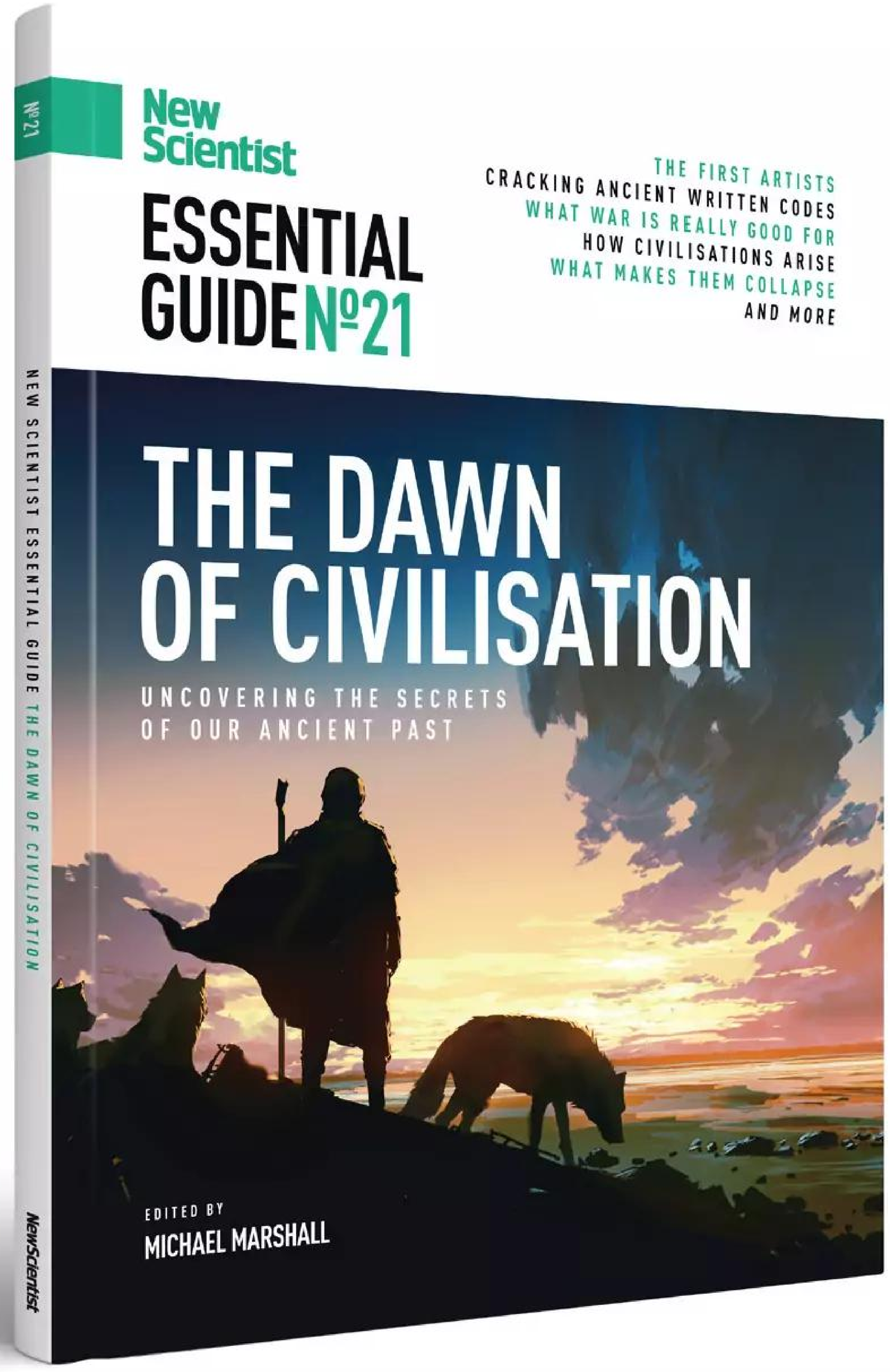

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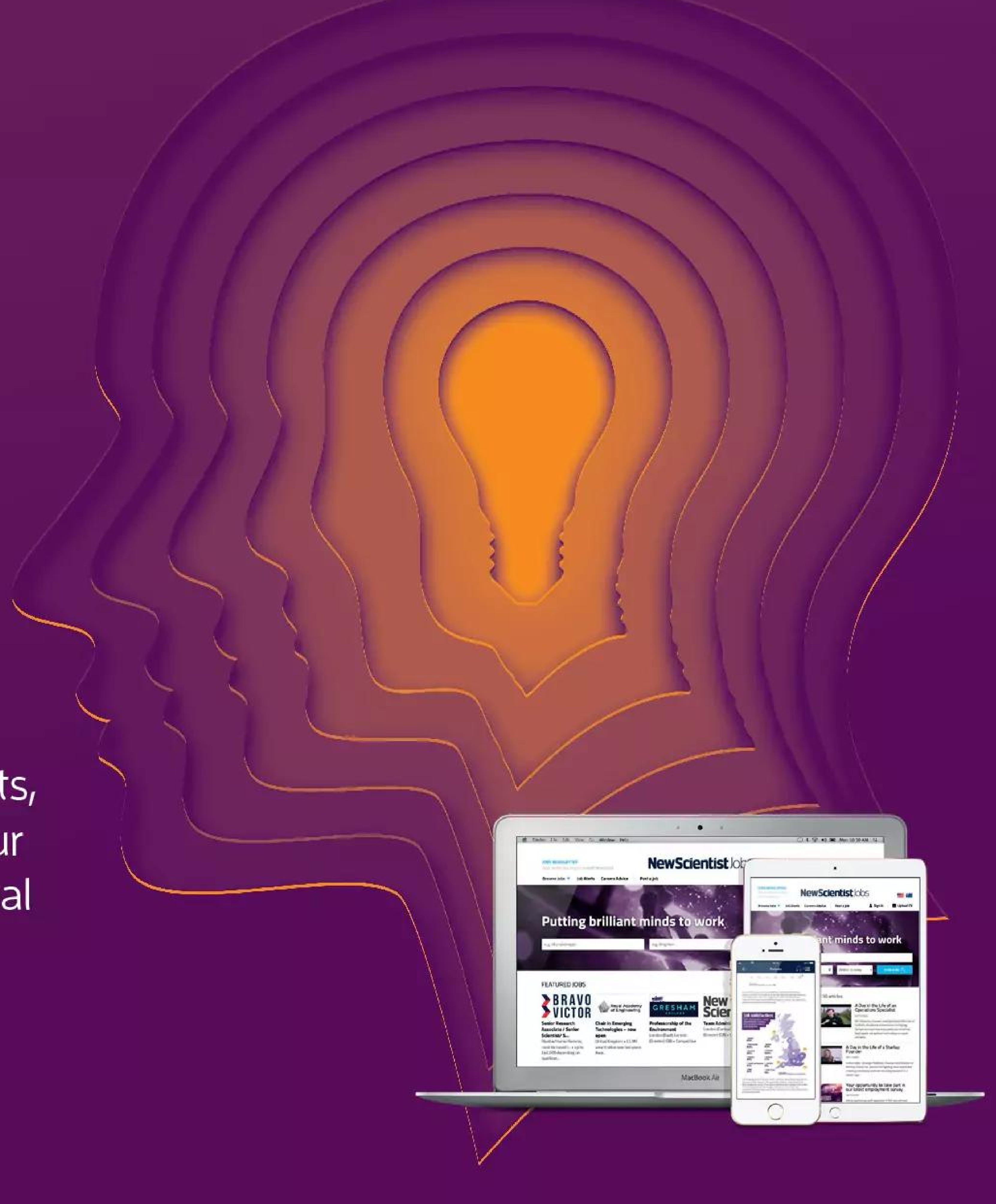
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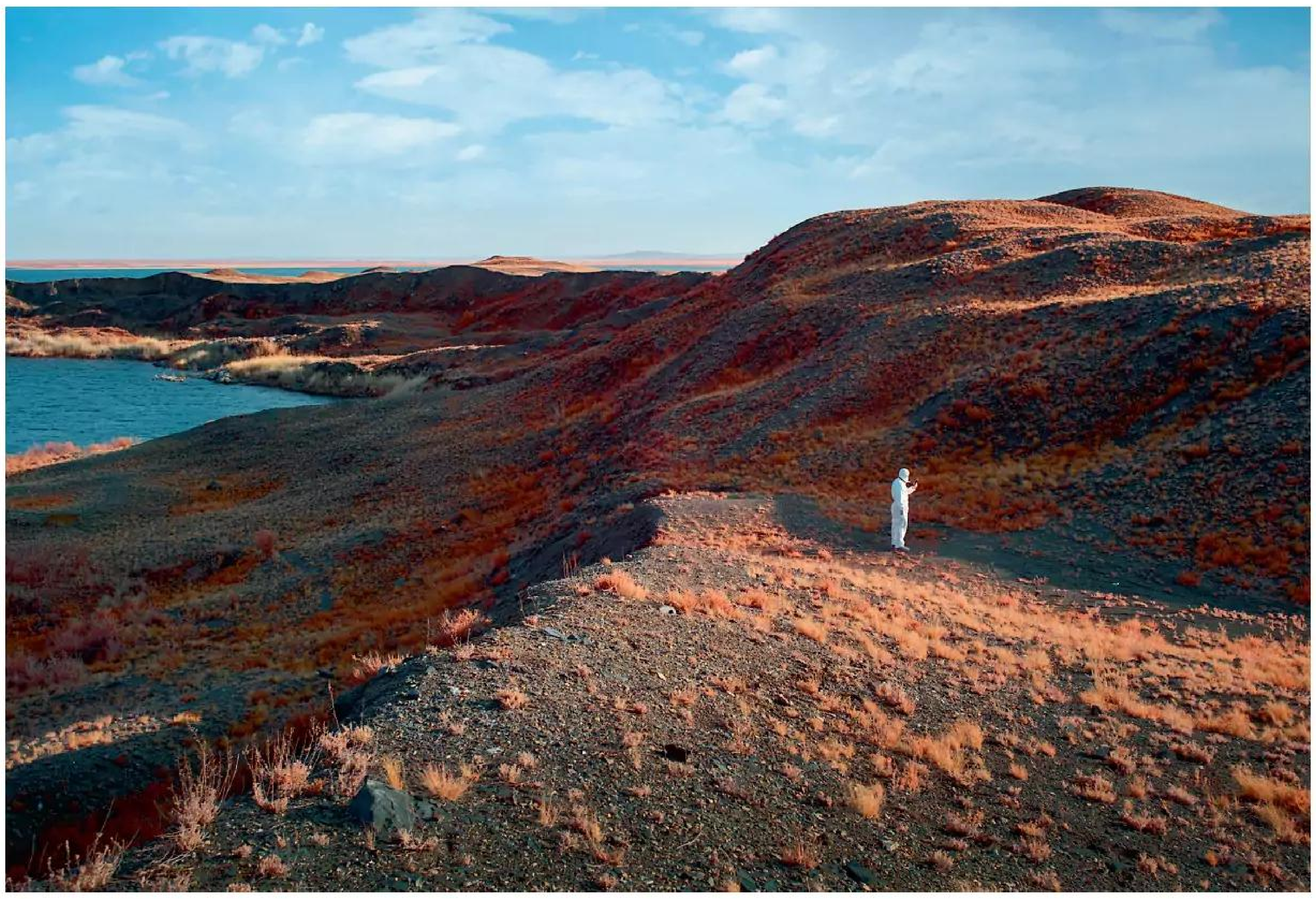

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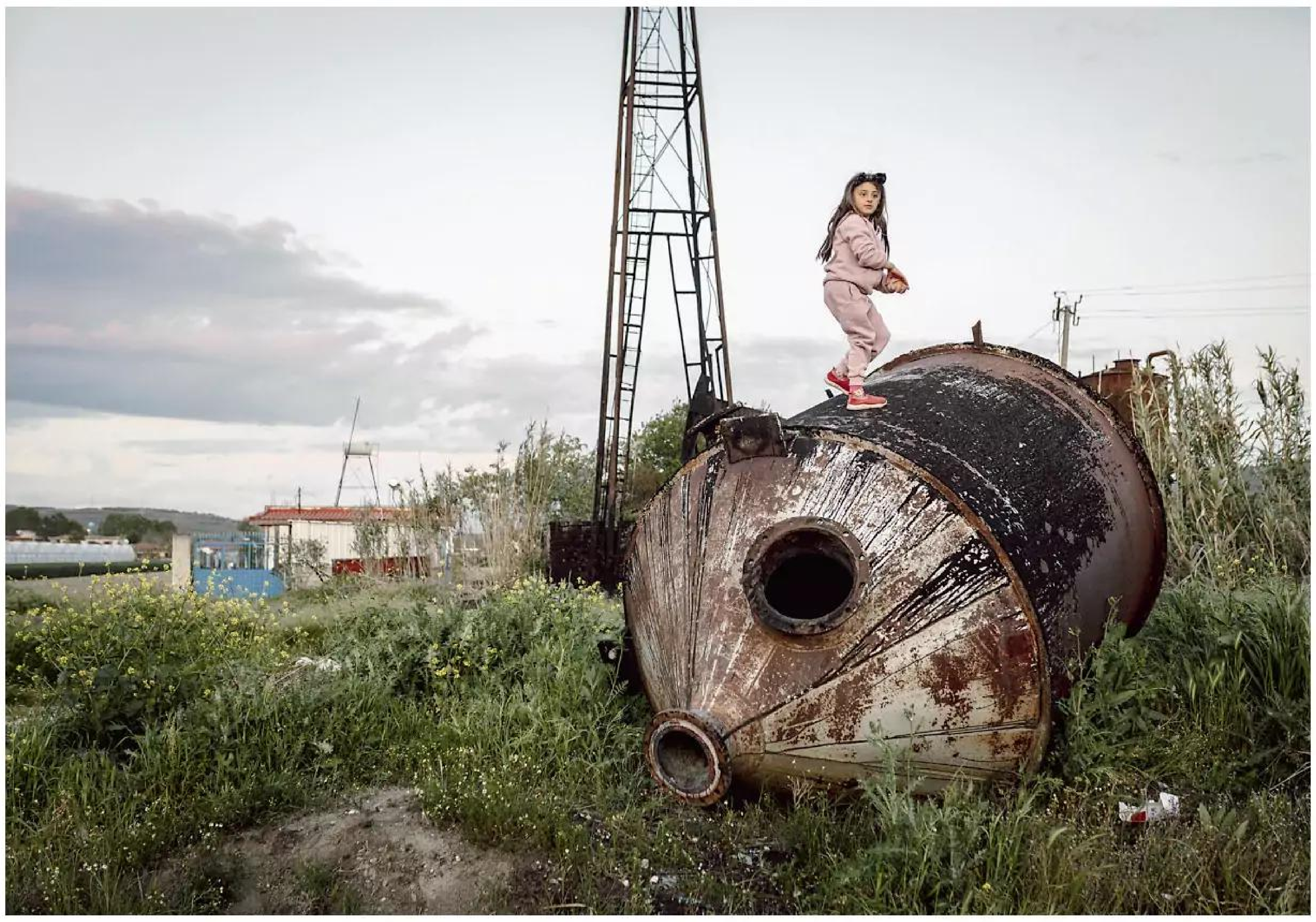

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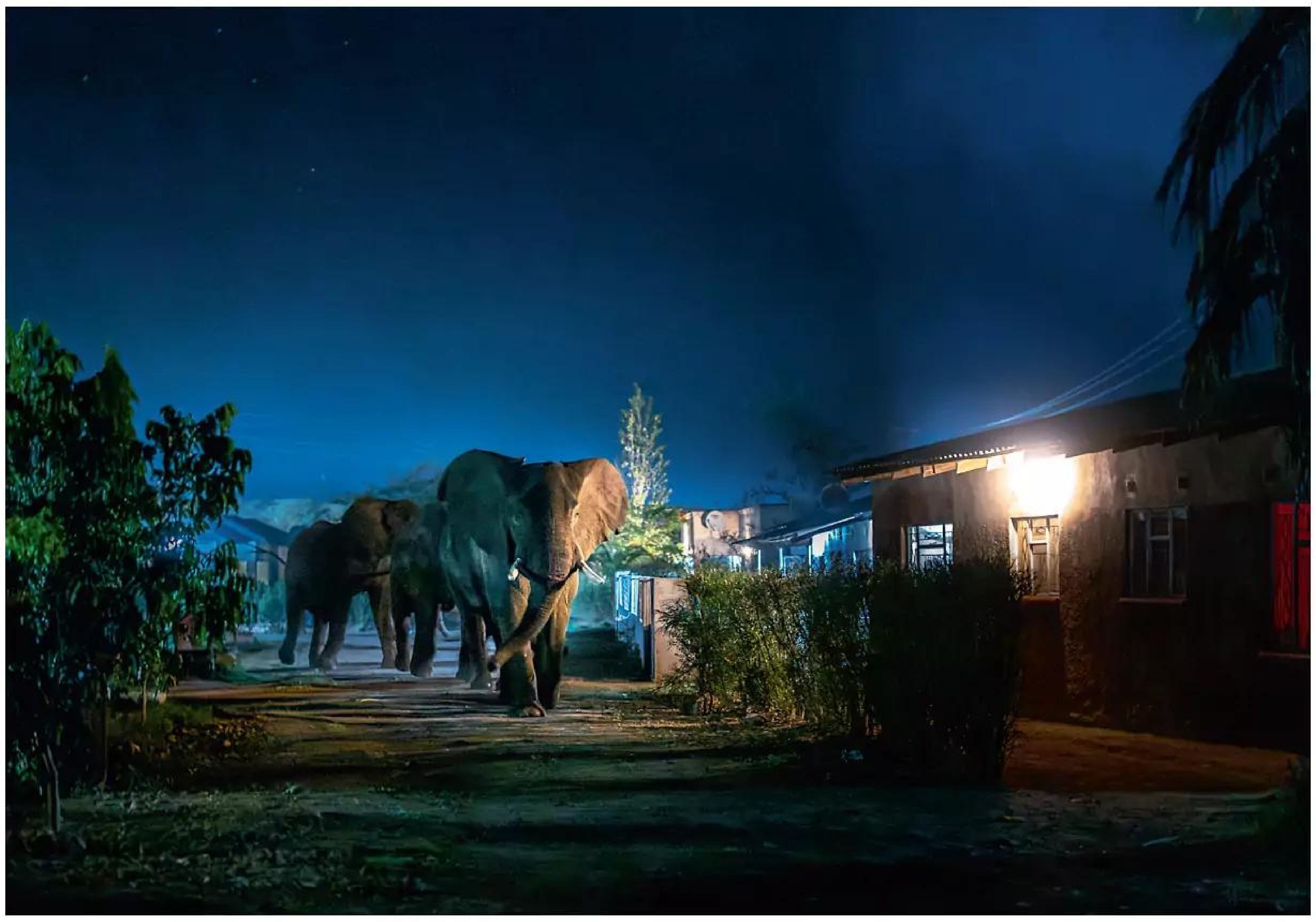

JASPER DOEST, FINALIST, PROFESSIONAL COMPETITION, WILDLIFE & NATURE, SONY WPA 2024

Worlds apart

Sony World Photography Awards
World Photography Organisation

THESE photos, all shortlisted for the Sony World Photography Awards 2024, strike at the heart of human vulnerability and the fragility of nature.

Eddo Hartmann is a finalist in the Landscape category for his series *The Sacrifice Zone*, referring to a remote part of Kazakhstan that was the major testing ground for the Soviet Union's nuclear experiments from 1949 to 1989.

The top near-left image shows a dosimetrist measuring radiation levels at Kazakhstan's Lake Shagan. This area remains highly contaminated from the 450 or so nuclear tests carried out there. The main picture (far left) shows what remains of an observation tower at Opytnoe Pole in Russia, another area used for Soviet nuclear tests.

Hartmann used infrared to capture these landscapes, with the red hues evoking radiation contamination, which can't be seen by the naked eye. "Local scientists utilise infrared technology to monitor the current conditions of contaminated sites," he says. "The chlorophyll present in green vegetation reflects a substantial amount of infrared light. The various shades of reflection provide valuable insights into the overall health of the environment in the specified area."

Elsewhere, a girl climbs onto an old oil tank in the Albanian village of Zharrëz (near left, centre). This image, taken by Jonas Kakó, is shortlisted in the Environment category. Below it, Wildlife & Nature finalist Jasper Doest captured elephants charging through Livingstone, Zambia.

The winner of the competition will be revealed on 18 April, before an exhibition at Somerset House, London, from 19 April to 6 May. ▮

Gege Li

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Transforming clinical trials

The UK has remodelled its ecosystem for clinical trials to create a world-leading landscape for life sciences research and development

James O'Shaughnessy is clear about the rationale for making new healthcare treatments easy to trial in the UK. "Without research, there are no improvements in care," he says. Clinical trials bring early access to pioneering treatments. Then there's the investment in local research facilities and big opportunities for the academic and industrial research community.

O'Shaughnessy should know. As the chair of the UK Government's review of commercial clinical trials, he has studied the landscape of life sciences research in detail. His report has been hugely influential in the UK regaining its position as a world leader in hosting clinical trials.

Pharmaceutical giant Moderna, for instance, has begun a £1 billion investment in UK-based operations. "When we started to look globally at where we might want to set up additional investment, the UK stuck out very prominently," says Melanie Ivarsson, Chief Development Officer at Moderna. "There are many great locations in the world for running clinical trials, but the UK is a leader because of its progressive regulator," she adds. "All that, combined with an extraordinary willingness and enthusiasm to invest in the life sciences sector, meant that the UK was an obvious choice."

It's a welcome turnaround, because the UK's hold on this sector had started to slip for a number of reasons. One was that other countries made a concerted effort to gain a slice of the pie. "It is a competitive field and other countries decided to go after this area and have done really well," O'Shaughnessy says.

Another is that, while the covid-19 pandemic demonstrated the UK's skills in this area, it also exposed the limits of its infrastructure. The UK's Medicines and Healthcare products Regulatory Agency (MHRA) was the first regulatory body in the world to approve a covid-19 vaccine.

But that rapid breakthrough came at a cost: delays to other, less urgent trial approvals. "By the end of June 2023, we had a significant number of clinical trials [awaiting approval]," says Andrea Manfrin, Deputy Director of Clinical Investigations and Trials at the MHRA. The statutory timeline for the initial review was 30 days but some trials were waiting 150 days.

Aware that something was awry, in February 2023 the UK Government commissioned O'Shaughnessy to review the sector. Change has come quickly since the publication of his findings in May.

During the summer of 2023, the MHRA made the decision to redistribute its staff and apply a different approach to the assessment of clinical trials. Where every trial had been approached and assessed in the same way, resources are now allocated depending on their specific risks.

So a trial that is deemed high risk, receives rigorous assessment to ensure the safety of the patient. But one that is lower risk—using known medication in a new way, for example—requires less assessment and potentially can be approved more quickly. "It's a balanced effort, according to the perceived risks and benefits," Manfrin says.

The outcome has been hugely important and since March 2023, the MHRA has been meeting and even surpassing its statutory timelines for clinical trial applications.

But it's not just about efficient assessment of clinical trial applications. The lessons learned from O'Shaughnessy's report are now being used to foster even more innovation, such as having a larger and more diverse set of people enrolled in clinical trials, and digital health technologies, like smartphone apps, that make it easier to take part.

O'Shaughnessy is also excited about the potential of artificial intelligence. "We can use this to look for the kind of patients that would be suitable for trials," he says. What's more, AI can comb through the National Health Service's (NHS) datasets to find clues that help speed diagnosis and treatments.

All of this has to prioritise safety, transparency and ethics, O'Shaughnessy points out. "Understandably, people care about how their data is used," he says. "They want to know it's not just secure, but that how it's being used aligns with the values of the NHS." And using that data in full compliance with privacy law is vital, of course.

The NHS is also a key enabler for clinical trials, Ivarsson reckons. "The NHS is incredibly unique – and very important to us," she says. That's because of its "joined-up" healthcare, where

> **"When we started to look globally at where we might want to set up additional investment, the UK stuck out very prominently"**
>
> Melanie Ivarsson, Moderna

James O'Shaughnessy
Chair of the UK's review of commercial clinical trials

Andrea Manfrin
Deputy Director of Clinical Investigations and Trials, Medicines and Healthcare products Regulatory Agency

Melanie Ivarsson
Chief Development Officer, Moderna

ORIENTFOOTAGE/ISTOCK PHOTO

pharmaceutical companies or academic researchers can conduct trials using patients drawn from across the whole country. Also helpful is the UK's natural diversity: the NHS is a source of trial patients that reflect all of the various groups of people that will ultimately use a new medicine.

Add that to the UK's openness to innovation and the country is once again fertile ground for pharmaceutical research. That's why Moderna is building a new research facility in Harwell, Oxfordshire. There will be offices and laboratories for researching biomarkers – biological indicators that can help diagnose disease – and a manufacturing facility. "It will produce about 100 million doses of vaccines a year and that could be increased to 250 million in a pandemic," Ivarsson says. Moderna is also investing in research and development personnel, including academic fellowships and PhD studentships, across the UK.

The MHRA is working hard to bring in further innovation to build on this success. "We are aiming to be an agile regulator, where patient safety is paramount but we are still enabling new medication to be available in a fast and safe way," says Manfrin.

O'Shaughnessy agrees that this is entirely possible: leadership with covid was just a glimpse of what the UK can achieve. The plan now is to double the number of UK-based clinical trials by 2027 and, beyond that, to establish the UK as a science and technology superpower.

"Our scientific strengths and our trial strengths meant that we were able to directly contribute to saving tens of thousands of lives," he says. "Now we can rediscover that energy in a post-pandemic world where we're not just focusing on one disease, but on the whole range."

Listen to the full interviews with James O'Shaughnessy, Andrea Manfrin and Melanie Ivarsson at newscientist.com/clinicaltrials

Life and climate, a co-production

The histories of Earth's climate and ecosystems are completely connected, as a smart, whistle-stop tour of the past makes clear, says **Michael Marshall**

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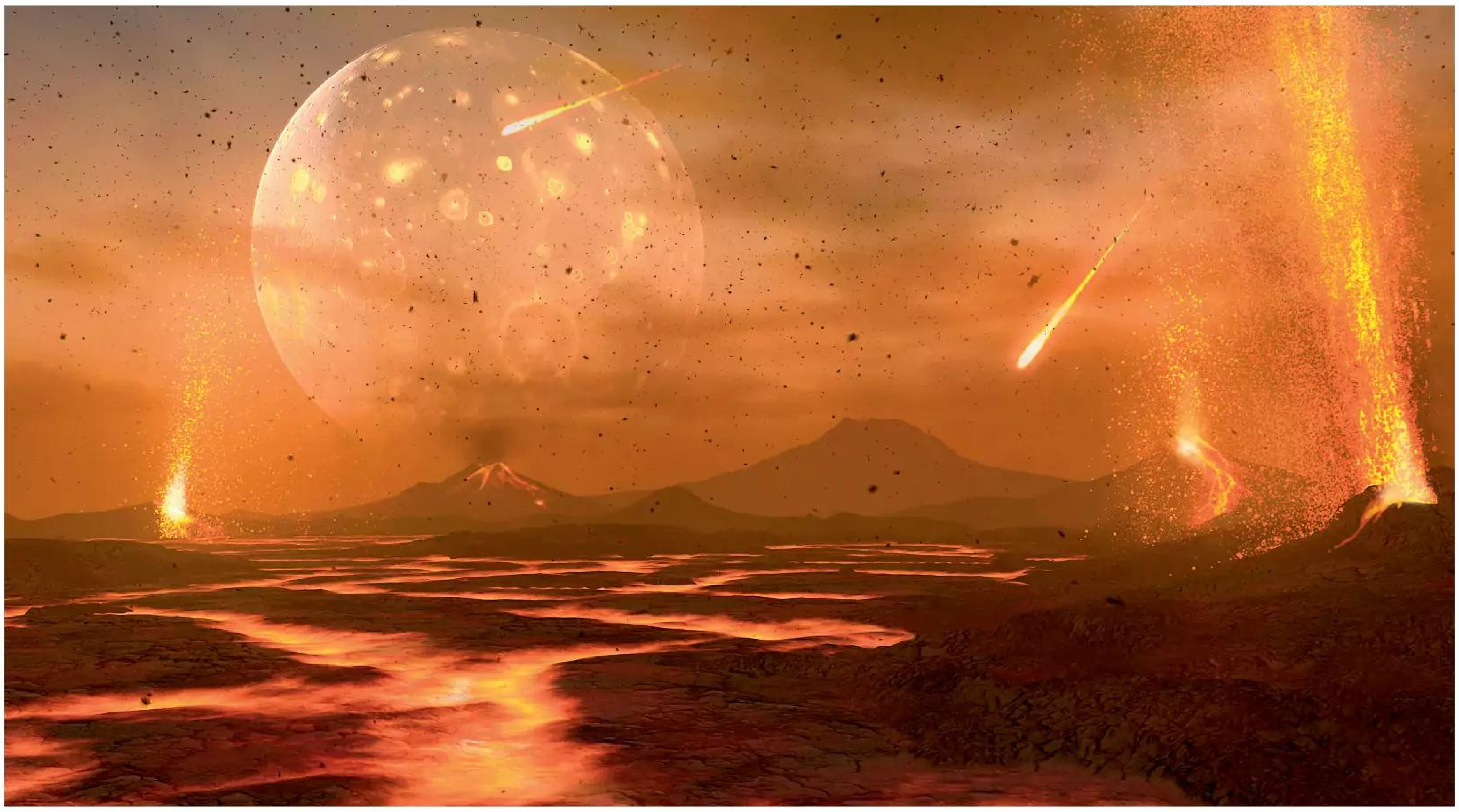

SHUTTERSTOCK/SILVAE

Once the first life took hold on Earth, it started influencing the climate

IT IS is a truism to say that life and climate are intertwined. Living organisms can change Earth's climate by, say, pumping out or absorbing the greenhouse gases that warm the planet. Equally, climate affects life by making conditions too hot, too cold or too dry for some organisms to survive.

This means that the story of life is also the story of climate, as *The Story of Earth's Climate in 25 Discoveries: How scientists found the connections between climate and life* makes clear. Its author, palaeontologist Donald Prothero, takes on the hefty task of recounting how life and climate have shaped each other during Earth's 4.5-billion-year history. Amazingly, he mostly succeeds.

The book is the latest in a series that are essentially extended listicles – with all the good and bad that implies. In his previous books, Prothero told us about dinosaurs in 25 discoveries, life in 25 fossils and Earth in 25 rocks. This time, it is 25 discoveries about past climates and how these shaped life and were shaped by it.

The 25-chapter format keeps things snappy. Each is rarely more than 20 pages long and there are a lot of photographs and illustrations. It is very much a whistle-stop tour.

Prothero tells the story chronologically, beginning with Earth's formation. In fact, he kicks off with the big bang, the expansion of the universe and the likelihood of extraterrestrial life, which – as he acknowledges – is stretching the definition of "climate" just a bit. I found these early chapters frustrating: although they were well-told, I wanted Prothero to get on with it.

However, from the third chapter onwards, he gets stuck into the early history of Earth, showing that he has a firm handle on issues such as the origin of the planet's water and the composition of the early atmosphere. He also regularly recounts snippets of science history. Astronomer Carl Sagan makes an early appearance, pointing out that the newly formed sun was fainter than it is now, so the young Earth must have kept itself warm, perhaps with greenhouse gases.

The book rapidly skips over billions of years, with chapters on the rise of atmospheric oxygen, caused by photosynthetic microorganisms, and on the Snowball Earth episodes, when most or all of the planet froze over in truly extraordinary ice ages.

In the second half of the book, Prothero focuses on the past 600 million years, when complex animals and plants appeared and spread all round the world. Each of the "big five" mass extinctions gets its own chapter, as do the switches between greenhouse and icehouse climates on Earth – accompanied by enormous rises and falls of sea level.

> **"The book is the latest in a series of extended listicles – with the good and bad that implies"**

These chapters can get bogged down in palaeontology: in his zeal to describe ecosystems, Prothero sometimes smothers passages in species names. At the risk of being accused of dumbing down, I think these would have benefited from less technical detail and more evocative imagery. I found myself skipping ahead to get to the next climatic shift.

On the positive side, the chapter on the end-Cretaceous extinction is a knockout. Prothero has a big problem with the notion that an asteroid impact was the sole cause of this mass extinction, and also with what he sees as an excessive focus on dinosaurs at the expense of other groups. The whole tone and pace shifts as Prothero moves into fifth gear and explains why it is a bit more complicated than "big rock hits, everything dies".

For someone like me who has been writing about the role of climate in evolution for over a decade, the material in the book was largely familiar and surprises were few and far between. But for the vast majority (including scientists from unrelated specialisms), Prothero's book will be an excellent quick-fire guide to the topic. It is rich with concepts, stories and characters – and there is always another apocalypse just a few pages away. ▮

Michael Marshall wrote The Genesis Quest: The geniuses and eccentrics on a journey to uncover the origin of life on Earth. He is based in Devon, UK

A world to win...

Dune defeats most directors. How does Denis Villeneuve fare in the second instalment of his take on the novel, asks **Simon Ings**

Film

Dune: Part Two

Denis Villeneuve

On general release

SO HERE is where we are at in the concluding half of Denis Villeneuve's adaptation of Frank Herbert's epic *Dune*.

Young Paul Atreides (Timothée Chalamet) has been cast into the wilderness of the arid planet Arrakis by the invading force of House Harkonnen. There, he learns the ways of the desert, embraces his genetic and political destiny and becomes, in one swoop, a focus for fanaticism and (with an eye to a third film – an adaptation of Herbert's sequel, *Dune Messiah*) the scourge of the universe.

From Alejandro Jodorowsky's mid-1970s effort, which never came to fruition (but at least gave Swiss artist H.R. Giger of *Alien* fame his entry into movie design), to David Lynch's 4-hour-plus farrago, savagely edited prior to its 1984 release into something closer to 2 hours that approached (but only approached) coherence, the industry assumption has been that *Dune* is an epic too vast to be easily filmed. However, throw enough resources at it, goes the logic, and it will eventually crumble.

That this is precisely the wrong lesson to draw was perfectly demonstrated by John Harrison's 2000 mini-series version for the Sci Fi Channel and its sequel, *Children of Dune* – both absurdly under-resourced, both satisfying stories that the fans paid attention to, even if the critics didn't.

> "In its rise, humanity has bred and warped individuals into something like gods"

Now we have Villeneuve's latest effort. Like his *Blade Runner 2049* (which is by far the better movie), it uses visual stimulation to hide the gaping holes in its plot. Yes, the story of *Dune* is epic. But it is also, in the full meaning of the word, weird. It is about a human empire that has achieved cosmic scale, and all without the help of computers, thinking machines and conscious robots, which were overthrown long ago in some shadowy phase of the *Dune* universe known as the "Butlerian Jihad".

In its rise, humanity has bred, drugged and otherwise warped individuals into becoming something very like gods; in conquering space, it teeters on the brink of attaining power over time. The drug-like "spice" mined on Arrakis isn't just a rare resource over which great rivals fight, but the spiritual gateway that makes this version of humanity, in the far future, viable in the first place.

Leave any one of these elements undeveloped (or, as here, ignored) and you are left with an awful lot of desert to fill with battles, swordplay, explosions, crowd scenes and giant sandworms. Here, an as-yet-unwritten rule of special effects cinematography comes into play, because I swear that the more those supersized wrigglers cost, the sillier they get. Your ears will ring, your heart will thunder and by morning the entire experience will have evaporated, like a long (2-hour-and-46-minute) fever dream.

What of the acting? As "Beast" Rabban, Dave Bautista outperforms the rest of the cast to a degree that is embarrassing. The Beast is a Harkonnen, an alpha predator in this grim universe, and yet Bautista is the only actor here capable of portraying fear. Javier Bardem's desert leader Stilgar is played for laughs (but let's face it, name one desert leader that hasn't been). Chalamet stands still in front of the camera; his love interest, played by Zendaya, scowls and growls like Bert Lahr's Cowardly Lion in *The Wizard of Oz*.

Dune: Part Two is an expensive film that has had the decency to put much of its $190 million budget in front of the camera. This makes it watchable, enjoyable and even, at times, thrilling. Making a good *Dune* movie requires a certain eccentricity, though. Villeneuve is, on the contrary, that deadening thing: "a safe pair of hands". ▮

Simon Ings is a writer based in London

Giant sandworms play a big role in *Dune*'s desert vista, but also in the special effects budget of this epic

WARNER BROS. PICTURES

New Scientist *recommends*

Chelsea Whyte
US editor
New York

I am listening to a new podcast called **Never Post**, made by a collective of writers, independent producers, researchers, composers and creators, which explores the internet's cultural power and how we use it. Hosted by Mike Rugnetta, an insightful observer of online goings-on, the first episode has a fascinating discussion about "posting disease" – when people can't stop posting even when it harms them – and how to avoid this.

There are also a set of delightfully mystifying interludes in which a man tries to buy caffeine-free Diet Dr Pepper, the availability of which has been debated online.

I have loved the internet since it entered my life in the 1990s and this show feels like a truly native exploration of it.

I also enjoyed **Chants of Sennaar**, a gorgeously hand-drawn video game about linguistics. To move up a mysterious ziggurat, you must solve puzzles and use clues to decipher languages the people around you speak, each with differing syntax rules. It is a tricky, enchanting little game.

CHARTS & LEISURE

Islands of wonder

A zoologist's exploits in Indonesia, with exotic beasts and wild men, reads like an adventure story. But in important ways, it is the real deal, says **Simon Ings**

Book
The Tomb of the Mili Mongga
Samuel Turvey
Bloomsbury: out now in the UK; 30 April in the US

IT MUST have been disconcerting for biologist Samuel Turvey as he hunted for fossils in a cave on the Indonesian island of Sumba between 2011 and 2014. He attracted the close attentions of "huge tail-less whip scorpions with sickening flattened bodies, large spiny grabbing mouthparts, and grotesquely thin and elongated legs".

In *The Tomb of the Mili Mongga: Fossils, folklore, and adventures at the edge of reality,* Turvey shares more exotic animals and worlds. But why was an evolutionary biologist hunting fossils? The answer has to do with the dual nature of islands. Life, he says, "does spectacular, ridiculous, experimental things on islands, making them endlessly fascinating to students of evolution".

Take New Caledonia, an archipelago that is about 1200 kilometres east of Australia and is a fragment of the ancient supercontinent Gondwana. It boasts bizarre aquatic conifers and even shrubby parasitic conifers without any roots. Then there is Madagascar, which hosts the aye-aye – a primate equivalent to the woodpecker in its ability to penetrate wood in search of food.

My favourite in Turvey's book of wonders is the now extinct cave goat *Myotragus* that lived on predator-free Majorca and Menorca. Relieved of the need to watch its back, it evolved front-facing eyes, giving the creature the appearance of a person wearing a goat mask.

BELOW: SHUTTERSTOCK/FAIZ ZAKI; RIGHT: THORSTEN NEGRO/ALAMY

The aye-aye (above) is a Madagascan lemur; a village (below) on Sumba, eastern Indonesia

But island life is also incredibly vulnerable. The biggest killers by far are visitations of fast-evolving diseases. From the 16th to 19th centuries, exploration and colonisation by Europeans decimated human populations of Pacific archipelagos, as a first wave of dysentery was followed by smallpox, measles and influenza.

Animals brought on the trip proved almost as catastrophic. Contrary to cliché, Westerners on Mauritius didn't hunt the dodo to extinction – rats did. And let's not forget Tibbles, the cat who, along with her offspring, is said to have wiped out the Stephens Island wren in 1894.

There are lessons to be learned, of course. Islands may be treasure troves of evolutionary innovation, but most of their treasures are already extinct. As for conserving their wildlife, Turvey asks how, without a good understanding of the local fossil record, "we even define what constitutes a 'natural' ecosystem, or an objective restoration target to aim for".

A tale of islands and their ephemeral delights would have made for an arresting book, but Turvey, an excellent raconteur, can't resist spicing up his account with tales of Sumba's mythical wild men, the giant, Yeti-like "Mili Mongga", who, it is said, used to build walls and help out with the ploughing – until their habit of stealing food got them all killed by the infuriated human population.

Why should we pay attention to such tales? Well, Sumba is just 50 kilometres south of Flores, where, in 2003, an Australian team unearthed an unknown, 1-metre-high hominin. If there were tiny hobbits on Flores, might there have been giants on Sumba? Might surviving Mili Mongga still be lurking in the forests?

Turvey uses local legends to launch fascinating forays into the island's history and anthropology, to explain why large animals, fetched up in such places, grow smaller, while small animals grow larger. He also has fun, largely at his own expense.

When one villager describes a Mili Mongga skull as being 2 feet long with teeth "as long as a finger", "I got the feeling," says Turvey, "that there might now be some exaggeration going on." Never say never, though. Soon, Turvey and his long-suffering team are following gamely, on missions up crags and past crocodile-infested swamps and into holes – sometimes ones where visitors from other villages go to relieve themselves.

The levity continues. "There was the cave that some village kids told us contained a human skull, which turned out to be a rotten coconut under some bat dung," recalls Turvey. "There was the cave that was sacred, which seemed to mean that no one could remember exactly where it was."

> **"Islands may be treasure troves of evolutionary innovation, but most of their treasures are already extinct"**

Turvey's serious explorations unearth two new mammal genera (ancestral forms of rat). He and his team don't bring back evidence of a new hominin, of course. But what's not to enjoy about a tall tale, especially when it paints such a vivid and insightful portrait of a land and its people? ▮

Simon Ings is a writer based in London

Editor's pick

Blue eyes: useful and quite alluring too

10 February, p 9

From Liz Reuben,
Canberra, ACT, Australia

Michael Le Page reports on a possible genetic advantage for blue eyes: the ability to see better in low light. Meanwhile, your review of Liat Yakir's book, *A Brief History of Love*, notes her proposal that blue eyes are evidence for the relative success of sexual selection for this trait, people being "attracted to those who seem special in some way" (17 February, p 28).

I suggest the explanation isn't either/or. A genetic anomaly that isn't detrimental and might be advantageous may also be seen by others as a characteristic that is attractive in and of itself, whether because of the appearance it has or the ability it confers.

Time to ban the word 'particle' from physics

17 February, p 8

From Philip Le Riche,
Harpenden, Hertfordshire, UK

It seems to me that the quantum Cheshire Cat problem – just like the one-particle-at-a-time double-slit paradox – appears paradoxical only because, however much we are told not to, we still think of elementary particles as like billiard balls. Probably the word "particle" ought to be expunged from all courses on physics.

Lentils trump beef-rice any day of the week

24 February, p 19

From Roger Parkinson,
Wellsford, New Zealand

James Woodford reports on a new food product incorporating cultured beef cells into rice to get a higher protein version of the latter for a carbon dioxide cost of 6 kilograms per 100 grams of protein. This compares well with beef, but not with lentils, which have a lot more protein and a CO_2 cost of 0.84kg/100g of protein. An added bonus is that lentils don't require a new industrial process to make them and there are already lots of recipes for them.

Please donate your dead body to the polar bears

17 February, p 32

From Jim McHardy,
Clydebank, Dunbartonshire, UK

Your article on cannibalism prompted an idea related to the consumption of human remains. Polar bears are starving due to a lack of sea ice. Burials use up land, cremations cause air pollution and cannibalism is frowned upon. Wouldn't it be better if people agreed to donate their bodies after death to the polar bears for food? This raises some issues, such as the possibility of human diseases being passed to the bears. In which case, cooking might help.

From Herbert Fenn, Cooloolabin,
Queensland, Australia

If we have been eating each other for "at least a million years", why are there no recipes?

Algorithms may be culturally polarising

27 January, p 27

From Stephen Shaw,
Kendal, Cumbria, UK

The argument advanced in the book *Filterworld*, the subject of your review, is that the shift towards algorithmically curated feeds has homogenised culture. I would argue that it may also polarise culture. Take book recommendations of the type "Readers who bought Book X also bought Book Y". If one reader's first selection was *The Imitation of Christ*, while another's was *Mein Kampf*, recommendations for future purchases will probably push the two further apart, rather than bring them culturally closer.

Despite wrinkles, lunar landing was incredible

3 February, p 10

From Alfred Vouk,
Hubbards, Nova Scotia, Canada

Using the word "botched" to describe the landing of Japan's SLIM lunar probe isn't appropriate. You say that one of its thrusters failed during the descent. In spite of that, the plucky craft landed in one piece, sent some pics, went to sleep and then reawakened. "Off-nominal" or a similar word would have been a better choice.

The landing was historic. The fact that it touched down intact and highly accurately and that the engineers recovered from the accidental thruster failure make it an even greater accomplishment.

Not a spread I'd want to put on my toast

24 February, p 21

From Jon Atack, Radcliffe-on-Trent,
Nottinghamshire, UK

Jenny Chapman perhaps chooses the wrong substance to highlight the safety of processed foods. The "mechanical mixture" made through "the ingenuity of depraved human genius" that she mentions wasn't margarine as we know it. It was an unhealthy mixture of beef fat and vegetable oil.

Thanks for justifying my tree-staking annoyance

20 January, p 44

From Kate Phillipson,
Prestbury, Gloucestershire, UK

Whenever I see newly planted trees staked, I become annoyed. Now I feel even more justified in having this emotion, thanks to James Wong's piece, which explained how bad the practice is. How do we persuade organisations to stop misguidedly tying young trees to posts? Perhaps we could highlight that it is much cheaper and quicker to not do so and the time saved could be used to plant more freestanding trees.

On the pursuit of a car-free future

Letters, 24 February

From Bob Downie, Glasgow, UK

Pamela Manfield suggests that affordable car transport is essential in rural areas as public transport is limited or non-existent. The term "motonormativity" has been coined to describe the thought processes that overwhelmingly focus on the private car as the prime transport solution. It may not be current political orthodoxy, but greatly enhanced rural public transport is very doable.

From Ian McNicholas,
Waunlwyd, Blaenau Gwent, UK

Manfield couldn't have pointed out more clearly the big flaw in environmental policies: that city-centric thinking dominates.

What working from home has really exposed

10 February, p 21

From Sam Edge,
Ringwood, Hampshire, UK

On face value, Robin Dunbar's arguments about the health benefits of friendships favouring on-site working over doing so from home – whether some or all of the time – seem plausible. But the personal, environmental and financial gains for the individual, business and society of foregoing daily commutes far outweigh the problems he fears. In fact, I would say the work-from-home change has exposed our pathological dependence on the workplace to fulfil social functions that should come from local communities. ■

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Artificial kindness

Millions of us are turning to chatbots for emotional support. But can AI ever be capable of empathy? And what could possibly go wrong, asks **Amanda Ruggeri**

ONE HUNDRED days into the war in Gaza, I was finding it increasingly difficult to read the news. My husband told me it might be time to talk to a therapist. Instead, on a cold winter morning, after having fought back tears reading yet another story of human tragedy, I turned to artificial intelligence.

"I'm feeling pretty bummed out about the state of the world," I typed into ChatGPT. "It's completely understandable to feel overwhelmed," it responded, before offering a list of pragmatic advice: limit media exposure, focus on the positive and practise self-care.

I closed the chat. While I was sure I could benefit from doing all of these things, at that moment, I didn't feel much better.

It might seem strange that AI can even attempt to offer this kind of assistance. But millions of people are already turning to ChatGPT and specialist therapy chatbots, which offer convenient and inexpensive mental health support. Even doctors are purportedly using AI to help craft more empathetic notes to patients.

Some experts say this is a boon. After all, AI, unhindered by embarrassment and burnout, might be able to express empathy more openly and tirelessly than humans. "We praise empathetic AI," one group of psychology researchers recently wrote.

But others aren't so sure. Many question the idea that an AI could ever be capable of empathy, and worry about the consequences of people seeking emotional support from machines that can only pretend to care. Some even wonder if the rise of so-called empathetic AI might change the way we conceive of empathy and interact with one another.

It is fair to say that empathy is one of our species' defining traits, evolving as it did in lockstep with social interaction. And yet while we all know instinctively what empathy is, it is actually quite a slippery concept.

One recent analysis, which looked at 52 studies published between 1980 and 2019, found that researchers frequently declared the concept had no standard definition. Even so, almost all frameworks of empathy, whether they came from philosophy, neuroscience, psychology or medicine, shared certain dimensions, says psychologist Jakob Håkansson at Stockholm University in Sweden, a co-author of the paper.

The researchers found that the empathiser must first be able to discern how the other person is feeling. They must also be affected by those emotions, feel them to some degree themselves, and differentiate between themselves and the other person, grasping that the other person's feelings aren't their own while still being able to imagine their experience.

On the first point, in recent years, AI-powered chatbots have made strides in their ability to read human emotions. Most chatbots are powered by large language models (LLMs) that work by predicting which words are most likely to appear together based on training data. In this way, LLMs like ChatGPT can seemingly identify our feelings and respond appropriately most of the time. "The idea that [LLMs] could learn to express those words is not at all surprising to me," says bioethicist Jodi Halpern at the University of California, Berkeley. "There's no magic in it."

But when it comes to the other criteria, AI still misses the mark in many ways. Empathy is interpersonal, with continued cues and feedback helping to hone the empathiser's response. It also requires some degree of intuitive awareness – no matter how fleeting – of an individual and their situation.

Consider someone who cries while telling a doctor she is pregnant. If we know her history of trying for years to conceive, we can imagine that her tears mean something different than, say, if she didn't want to have kids.

Current AIs are incapable of that kind of nuanced understanding. More to the point, says Halpern, is that they are incapable of feeling for the person they are interacting with. "We have no reason to think AI can experience empathy," she says. "It can produce a product – the language that mimics the actual empathy humans have. But it does not have empathy."

All of which helps to explain conversations like the ones I had with ChatGPT and, later, with Elomia, one of several commercial chatbots that now offer mental health support – and one that, according to its creators, has been used by more than 100,000 people. When

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GIACOMO GAMBINERI

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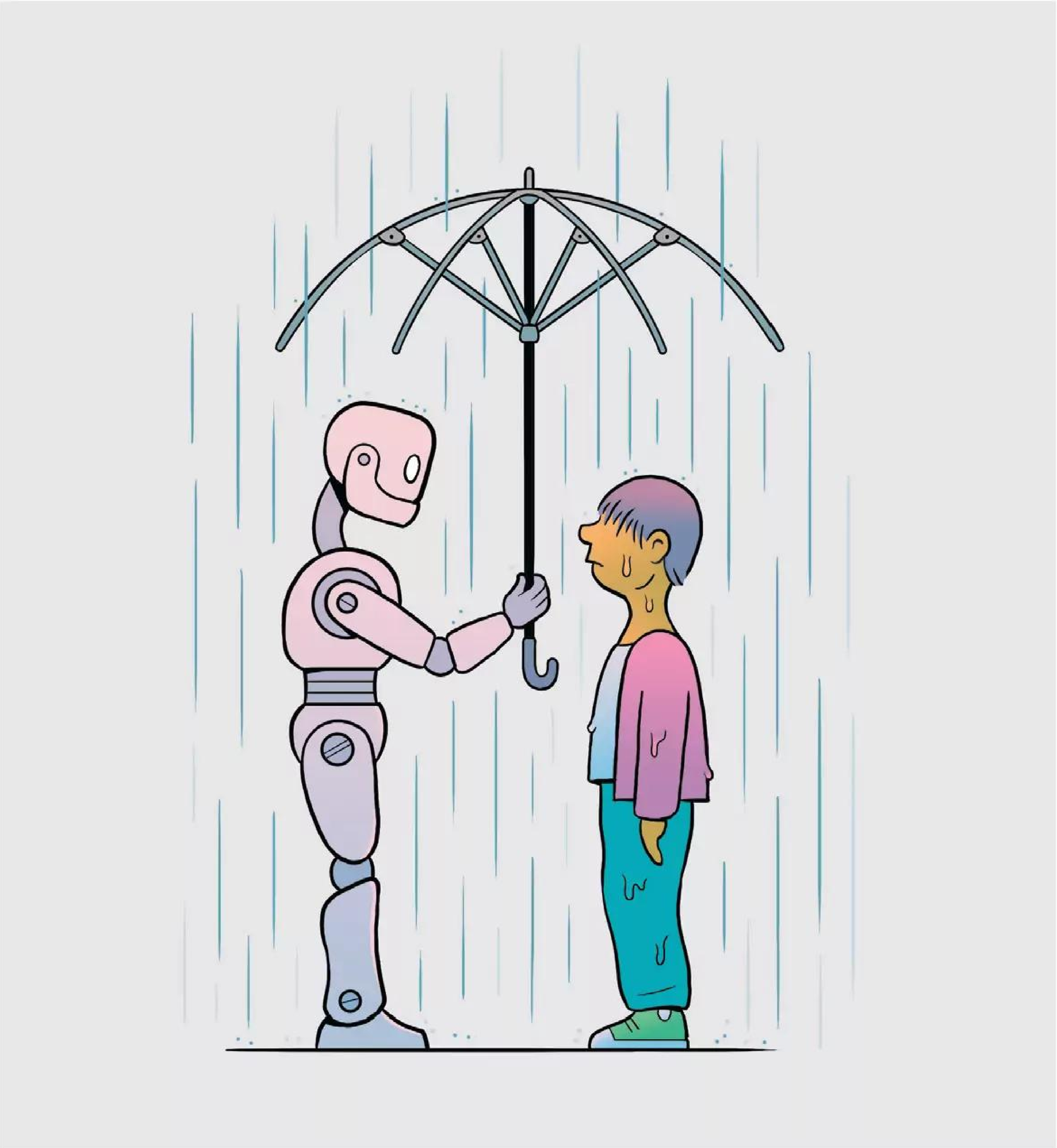
I told it how I was feeling about current events, it asked: "How does thinking about these situations affect your daily life and emotions?" "I'm finding it hard to cope," I responded. "I'm sorry to hear that," it said. "Are there any specific behaviours or thoughts that you've noticed?"

Every time I answered, Elomia immediately generated another question. The prompts gave me an opportunity to reflect. But what I really wanted was for someone to say, "Ugh, I know exactly how you feel," share their own struggles or give me a hug – not pepper me with questions. In other words, I was looking for a response that was genuinely empathetic.

The big question, then, is whether that is even possible. Some believe that AIs may, in fact, become capable of experiencing and sharing human emotions. One approach is to continue scaling up LLMs with ever vaster and more diverse datasets. Virtual agents build on the language-processing abilities of chatbots by also "reading" our facial expressions and vocal tone. Most complex of all are robots that analyse these features, plus body language and hand gestures. Rudimentary versions of these emotion-detecting bots already exist, but more input can also create confusion in them. "The more modalities we add to the system, the more and more difficult it becomes," says Elahe Bagheri at IVAI, a German start-up studying human-AI interaction.

Making machines that are more adept at reading emotions is still unlikely to create genuine empathy, though, says psychologist Michael Inzlicht at the University of Toronto in Canada, one of the researchers who wrote the paper praising "empathetic AI". "You need to have emotions to experience empathy," he says.

Some computer scientists argue that certain types of algorithm already experience primitive emotions – although it is a controversial position. These algorithms, called reinforcement learning agents, are rewarded for taking certain actions over others. The expectation of receiving a reward drives simple human survival instincts, such as seeking out food and water, too. We also expect and receive social rewards from each other that correspond to an array of human emotions, says Yoshua Bengio at the University of Montreal in Canada. The richness of our emotional palette is a result of the richness of our social interactions, he says. So the idea is that if you can capture similar social complexity in AI, then actual emotions – and perhaps empathy – could emerge.



> "SOME ARGUE THAT CERTAIN TYPES OF ALGORITHM ALREADY EXPERIENCE PRIMITIVE EMOTIONS"

Another approach hinges on mirror neurons: the brain cells thought to fire when we see someone performing an action or expressing an emotion, activating the same parts of our brain that would light up if we were to do or feel the same thing ourselves. Computer scientists have already built architectures that replicate mirror neurons, arguing that these are the key to AI empathy.

But over the past decade, some of the research on mirror neurons has been discredited and, what's more, we have learned that the brain areas where the cells reside may not even be directly related to emotion processing.

Ultimately, you can't really know what sadness is unless you have felt sad. The evolution of empathy is intertwined with social interactions and a recognition that other minds exist, too. Empathy emerges as a holistic whole, says Inzlicht. "You probably need consciousness to experience empathy." That is far from a given for AI, now or in the future.

But what if AI doesn't need genuine empathy to be useful? One online experiment from 2021 found that talking to a chatbot perceived as being caring still reduced stress and worry in people – albeit not as much as talking to their human partner. And in January, another chatbot, designed by Google to conduct medical interviews, was judged to have a better bedside manner than actual doctors by 20 people who were trained to impersonate patients – all while delivering more accurate diagnoses. Unlike humans, "an AI doesn't get stressed out or burned out. It can work 24 hours without getting tired," says Håkansson. However, the participants in the Google study didn't know whether they were speaking to a chatbot or a doctor. Empathy is a two-way process, so its

> **WE COULD START EXPECTING HUMANS TO EXPRESS TIRELESS EMPATHY LIKE CHATBOTS CAN**

effectiveness also depends on how we perceive and emotionally connect to the other person – or machine. Research shows, for example, that when people know they are interacting with an AI, they feel less supported and understood.

"This means AI has two bad alternatives," says Håkansson. Either the person doesn't know the AI is an AI and thinks it is human, which might be effective but unethical, or they know it is an AI and this makes it ineffective.

Then again, Inzlicht has just wrapped up as-yet-unpublished research that indicates a preference for AI empathy – even when users know it is AI. In his study, human participants and ChatGPT were given descriptions of different scenarios and asked to write short, compassionate answers. When other participants rated the various responses, they scored the AI responses as highest for empathy.

In the next part of the study, Inzlicht and his team labelled which responses were from AI and which were from humans. "What we found was that people still preferred AI," he says. Surprisingly, the labelled AI responses were even favoured over a subset of responses by Crisis Line Workers, who are expert deliverers of empathy. (Inzlicht's work builds on similar research by John W. Ayers at the University of California, San Diego, and his collaborators.)

Outsourcing empathy

This may be explained by the human tendency to project feelings onto objects – whether that is children playing with Tamagotchis or people conversing with chatbots like Replika that let you create an "AI friend". In conversational AI, research has found this inclination can be exacerbated by priming people to think that the AI really cares about them. "We begin to feel that it has feelings for us beyond what it is expressing or what it's capable of," says Sherry Turkle, director of the Massachusetts Institute of Technology's Initiative on Technology and Self. "This isn't a quality of the machines. This is a vulnerability of people."

And it is a weakness that many worry could be exploited – particularly given the question of what it means for an AI to be able to discern someone's emotions, but not to actually resonate with them or even care about them in a genuine way.

CHRIS MCGRATH/GETTY IMAGES

Shared emotions and experiences are at the heart of genuine empathy

"Say an AI detects that you're heartbroken because your boyfriend has just left you," says Wendell Wallach at the Carnegie Council for Ethics in International Affairs in New York. "It could seemingly commiserate with you and then slowly turn the conversation to you buying some product. That's just a very mild example. Even though the machine cannot feel, you are, in effect, being manipulated through your emotions." That, say Wallach and other researchers, wouldn't make AI empathetic. It would make it "psychopathic".

Concerns over the danger of machines that can "read" us but don't care about us are more than theoretical. In March 2023, a Belgian man reportedly died by suicide after six weeks of discussions with an AI chatbot. Media outlets reported that he had been sharing his fears about the climate crisis. The chatbot seemed to feed his worries and to express its own emotions – including encouraging him to kill himself so that they would "live together in paradise". Pretending at empathy to too great a degree without the common-sense guard rails that a human is likely to offer can, it appears, be lethal.

The possibility that we will increasingly turn to, and perhaps even come to favour, AI empathy over the human variety also concerns Turkle for a profound reason: it could change the nature of empathy itself.

As an analogy, she uses the Turing test, which was designed as a purely behavioural assessment for a computer's "intelligence". But its definition of intelligence – whether the computer could converse like a human – became a stand-in for our understanding of intelligence in general, even though human intelligence is much broader. Turkle suggests that we could start redefining empathy in a similar way – expecting humans to express empathy that is tireless, for example, but also less genuine or connected.

However, Inzlicht counters that we shouldn't be swayed by the critiques so much that we don't reap the potential benefits of empathetic-seeming AIs working alongside humans – whether as a quick assist for overstretched health practitioners or to relieve loneliness among older people, as the voice-operated AI "care companion" ElliQ is designed to do. Other researchers, including Turkle, argue that even this hybrid human-AI approach goes too far, as it will reduce key opportunities to practise and improve actual human empathy. We may end up turning to machines, rather than looking for ways to foster genuine connection, she says.

"It's a sad moment when we are actually thinking that being lonely can be fixed by a back-and-forth interaction with something that has no idea about what it is to be born, about what it is to die," says Turkle.

At the end of the day, despite talking to multiple chatbots online and getting more advice and reflective prompts than I knew what to do with, I found I still felt sad about the state of the world. I did what I knew I had to do all along: I picked up my phone and called a friend. ▮

Need a listening ear? UK Samaritans: 116123 (samaritans.org); US 988 Suicide & Crisis Lifeline: 988 (988lifeline.org). Visit bit.ly/SuicideHelplines for other countries.

Amanda Ruggeri is an award-winning journalist and editor based in Switzerland

Blow by blow

A new understanding of concussion is finally waking us up to the risk of contact sports – and ways to prevent the damage, says **Graham Lawton**

Pittsburgh Steelers' Hines Ward is hit by Tennessee Titans' Cortland Finnegan

IN NOVEMBER 2022, a young woman called Heather Anderson killed herself at an army barracks in Perth, Australia. Anderson was a former Australian Rules footballer who had been struggling with depression. Her family donated her brain to the Australian Sports Brain Bank, which confirmed what everyone suspected: Anderson had chronic traumatic encephalopathy (CTE), a degenerative brain disease linked to repeated blows to the head. She was the first professional female athlete to be diagnosed with this condition. She won't be the last.

Strange as it may seem, it has taken almost a century to get to grips with what a blow to the head really means. Most people are familiar with concussion, but now we know that even mild knocks to the head can cause long-term problems. "It is misleading to assume that when the physical force applied to the head is weak, the consequences will be less," says Allison Reiss at New York University.

These consequences are playing out primarily in professional athletes, several of whom are living under the shadow of CTE. Recently, we have seen many of them take legal action against governing bodies. But it isn't just athletes who are at risk. Even a single blow to the head can put a person in danger of future cognitive problems.

Thankfully, alongside the harms, there is a growing understanding of what happens to the brain after a knock, which is providing new targets for novel treatments together with

a plethora of new technologies that aim to protect people from its devastating effects.

Concussion, or a mild traumatic brain injury (MTBI) as it is formally known, is defined as a transient impairment of cognitive function after a head injury that can't be picked up by a CT scan. Sometimes, it includes a brief loss of consciousness and memory loss. A blow to the head like those that can be inflicted during a boxing match or contact sports causes the brain to slosh back and forth inside the skull like a gel in a mixing bowl, inflicting physical damage at the site of impact and on its opposite side. However, a blow isn't necessary to develop concussion – a combination of rapid acceleration, deceleration and rotation of the head, as is commonly seen in traffic accidents, is enough, says Elizabeth Sandel at the University of California, Davis.

According to figures from Norway, around 0.3 per cent of the country's population seek emergency medical attention for an MTBI every year, mostly after a fall, a sports-related collision, a traffic accident or violence. That, however, is likely to be an underestimate of the true numbers as most people don't go to hospital, says Ola Skjeldal at the University of Gothenburg in Sweden. The true incidence is thought to be around double that, according to the World Health Organization.

We know that MTBIs don't have to be repetitive to lead to long-term problems and it would be wrong to assume that "mild" injuries mean trivial outcomes. For reasons that aren't well understood, even a gentle blow can cause prolonged and debilitating symptoms. Most people with a one-off concussion recover within three weeks, but some 10 to 15 per cent don't. Their symptoms are varied and long term: migraine-like headaches, dizziness, fatigue, aversion to noise and light, blurred vision, flashing lights, neck pain, emotional volatility, depression, anxiety, memory problems, brain fog, insomnia, lower tolerance to alcohol and a preoccupation with the fear that permanent brain damage has occurred.

This so-called long concussion can lead to significant disability and a much-reduced quality of life, according to Grant Iverson at Harvard Medical School (see "What is long concussion?", p 38).

Things get even worse when people experience repeated bangs to the head. Increasingly, it appears that for some, CTE is the inevitable consequence.

There is a long history of CTE in contact sports. In 1928, a doctor called Harrison Martland published an article in *JAMA* ›

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What is long concussion?

The fact that some people with concussion don't recover in the expected time frame has been recognised for decades. The term "post-concussion syndrome" was first proposed in 1934, though it remained controversial for many years, in part because there was a perception that people were faking it in search of compensation.

But recently, post-concussion syndrome – or "long concussion" as it is often called – has risen up the medical agenda, propelled in part by the attention paid to chronic traumatic encephalopathy (see main story).

In 2019, researchers representing the Athlete Brain Health Foundation called for a paradigm shift in the way that people are treated and managed, starting with a rebranding. "Post-concussion syndrome" suggests intractability, they argued, which isn't true. Better to call it "persistent symptoms after concussion (PSaC)" instead. At the same time, there has been a shift away from passively waiting for symptoms to disappear to active intervention, according to Hana Malá Rytter at the Danish Concussion Center in Copenhagen.

There are many challenges to understanding long concussion. For a start, not everybody has the same set of symptoms, and many people who are ill with something else, such as chronic pain, anxiety or post-traumatic stress disorder, can have very similar ones. Such overlaps create a "fundamental challenge" in defining the disease, says Grant Iverson at Harvard Medical School. There is also a lot of uncertainty around why some people with concussion go on to develop long-term symptoms, while others don't. Iverson describes it as a "conundrum".

We are making headway, though. Research from the 1990s found that personal setbacks prior to the injury, such as financial hardship or problems at work, can predispose people to PSaC. More recently, Toril Skandsen at the NTNU Faculty of Medicine and Health Sciences in Trondheim, Norway, assessed 378 people on a range of factors prior to their injuries to see if certain individuals are at greater risk. She found some significant associations: being female, having a history of headaches and other pain, being unemployed or underemployed, having a neurotic personality type and low resilience, sleeping poorly and having symptoms of ADHD.

Again, why these predispose some people to PSaC isn't known, but it does offer the opportunity to intervene early when vulnerable people have a mild traumatic brain injury.

describing "a peculiar condition occurring among prize fighters", which fans and promoters called being "punch-drunk". Early signs were a staggering gait and mild mental confusion similar to being intoxicated; some fighters progressed to dementia. Martland suggested, unsurprisingly, that punch-drunkenness was caused by serial blows to the head. A few years later, the condition acquired a grand Latinate name, dementia pugilistica, or "boxer's dementia".

For many years, dementia pugilistica was regarded as a problem confined to boxing, but in 2005 a hammer blow landed. Bennet Omalu, then at the University of Pittsburgh in Pennsylvania, and his colleagues reported a case in former American footballer Mike Webster, who died suddenly aged 50 after experiencing cognitive impairment, mood changes and Parkinson's-like symptoms.

That set off a cascade of events that continues to play out today. On 17 February 2011, former Chicago Bears player David Duerson killed himself at his home in Florida. Prior to his suicide, he sent a text message to his family instructing them to donate his brain to Boston University School of Medicine, where researchers were studying CTE. They posthumously diagnosed him with the condition. A year later, another former footballer, Junior Seau, also died by suicide. In 2013, more than 4500 former athletes sued the National Football League (NFL) for concussion-related brain injuries and won $765 million in damages. In December last year, hundreds of former professional rugby union players initiated legal action against World Rugby, the Rugby Football Union and the Welsh Rugby Union claiming that these bodies had failed to put in place any reasonable measures to protect their heads. A spokesperson from World Rugby says on behalf of all three organisations: "The whole of rugby cares deeply about all of our current and former players, we will never stand still when it comes to player welfare. While we cannot comment on the ongoing legal action whilst we wait for the claimants to set out their arguments in full, nor reach out to the players involved directly, we would want those players to know that we listen, we care and continue to champion player welfare as the sport's number one priority."

Repetitive impact

CTE is a problem that won't be going away any time soon. Last year, researchers at Boston University reported that they had found CTE in 345 of the 376 former NFL players' brains they had examined, though they warned that this doesn't reflect the prevalence among ex-players as not all of them donate their brains to science. But it does suggest there is something very wrong: prevalence in the general population is extremely low, under 1 per cent. CTE has also been diagnosed in wrestlers, ice hockey and baseball players, a professional bull rider, a cyclist, military personnel exposed to blast injuries and people who have experienced domestic abuse.

Despite initial doubts about the cause of CTE, there is now clear evidence that it comes about through repeated blows to the head. More than 97 per cent of published cases of CTE are in people with a known history of repetitive head impacts, mostly from contact sports, according to Ann McKee at the US Department of Veteran Affairs in Boston. Empirical evidence backs this up. A recent study by William Stewart, now at the University of Glasgow in the UK, and his colleagues found that professional soccer players who headed the ball more and had longer careers were more at risk of CTE. He and his team have also found that international-level rugby union players are more at risk than the general population. "No game which involves repetitive head injury can be immune to this," says Stewart.

Sportswomen may be at even higher risk than their male counterparts. In soccer, for example, women report 1.5 times more concussions than men, perhaps because their neck muscles are generally weaker. Women also seem to endure more severe symptoms for reasons that aren't well understood.

While CTE tends to only be diagnosed post-mortem, by tell-tale tangles of an abnormal brain protein called tau in the cerebral cortex, it causes a range of symptoms in the living. These include disorders of cognition, mood, behaviour and movement and, in severe cases, dementia. But diagnosis is difficult, as these symptoms have largely been identified from interviews with people who knew deceased individuals diagnosed at autopsy with CTE. They can also be difficult to distinguish from mental health conditions and post-concussion symptoms. Blood and neuroimaging tests are in the pipeline, according to McKee, but in the meantime diagnosis is a bit hit and miss.

Symptoms of CTE can be managed, but there is no cure. There is, however, an increasing understanding of the neurological changes that occur after repetitive head injuries, which may offer targets for early intervention. They come in phases, a cascade of destruction that plays out over days, weeks and even years.

The first phase is excitotoxicity, caused by the release of chemicals from ruptured brain cells. The main culprit is glutamate, a neurotransmitter that activates receptors on other neurons. This principally causes neurons and support cells to become more permeable to calcium, which floods in and initiates a wave of destruction. Calcium-swamped cells activate various enzymes that attack membranes, proteins and DNA, leading to mass cell death.

The enzymes also attack mitochondrial membranes, causing these energy-producing organelles to disintegrate, setting off phase two, oxidative damage. This causes violently reactive compounds, which are usually sequestered inside mitochondria, to leak out. The concentration of these dangerous compounds can stay high for days. Phase three is neuroinflammation, which is quickly followed by a final round of cell death.

This final phase may offer the best target for treatment via inhibition of a class of enzymes called caspases, which are the main cause of cell death. Many caspase inhibitors are in development and may eventually be ready for use in humans with MTBIs, according to Reiss.

For now, the focus is on prevention, and there are several emerging measures that aim to reduce the risk. Many contact sports now have on-field procedures to diagnose and remove players with concussion, not just for professionals but at all levels. Around the world, both amateur and professional soccer players are being trained how to head the ball more safely, and some federations have banned heading altogether from youth soccer.

Technology is also playing its part. In October last year, World Rugby debuted its "smart mouthguard" in an international women's rugby match, before rolling it out for players in this year's Six Nations tournaments. The device monitors accelerations and flags any above set thresholds to medics. The player is taken off and assessed and, if need be, kept off. Flagged players may also be monitored after the game. This is the first of a raft of new technology that is likely to be a permanent fixture in future seasons. Researchers at the University of California, San Francisco, are also developing a headset to monitor recovery from concussion, while Stanford University in California is working on an American football helmet with liquid shock absorbers.

Of course, the safest way to avoid the potentially horrendous complications of head injuries is to avoid head injuries altogether. In 2021, the US National Institute of Neurological Disorders and Stroke agreed on how to diagnose CTE while a person is still alive. The leading criterion is "substantial exposure" to repetitive head injury.

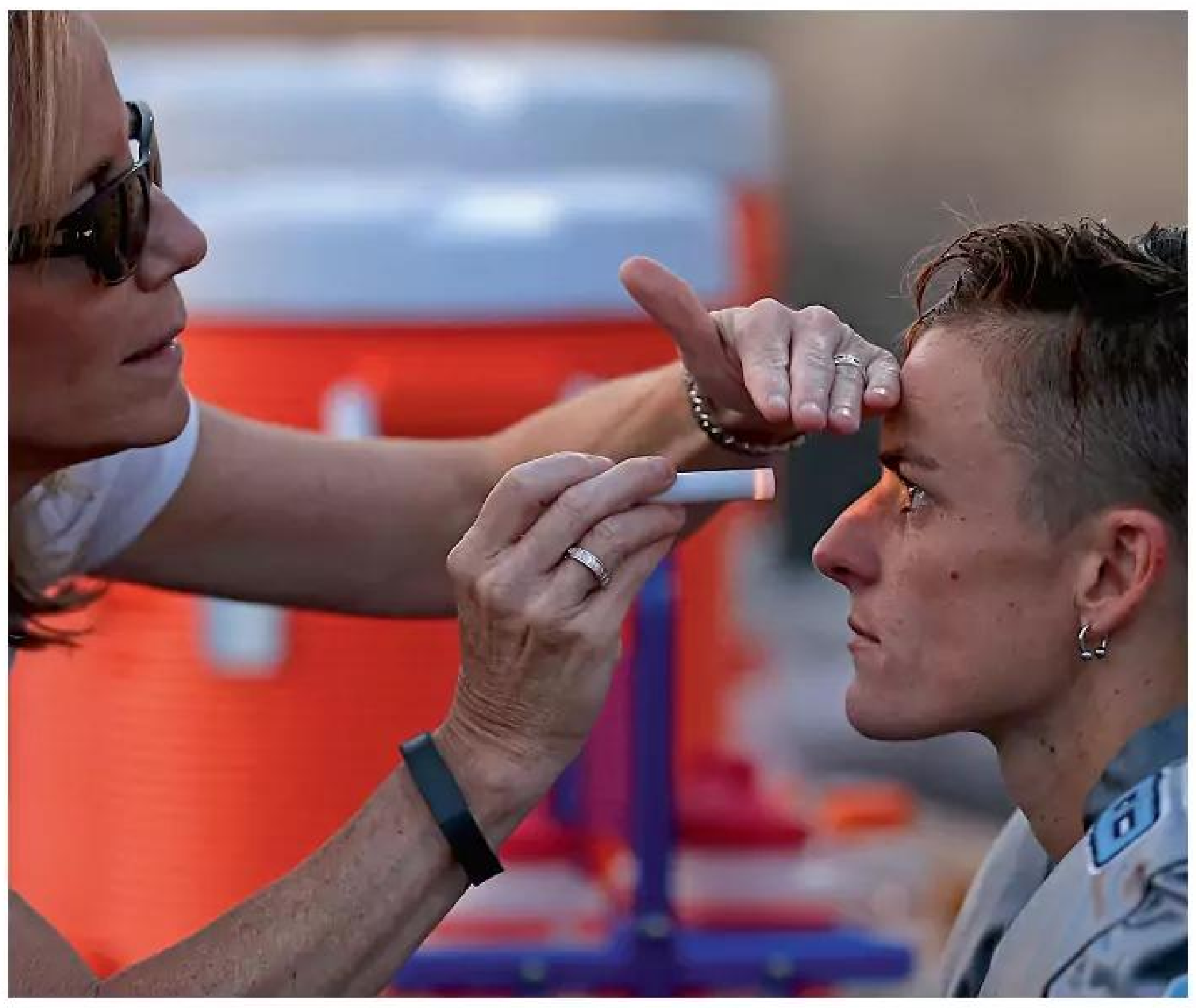
Stopping playing the sport you love or depend on for your income will never be an easy decision. But if head injuries are a risk you routinely take, it is well worth doing everything you can to protect yourself. ■

MARCELO POLETTO/SPP/SHUTTERSTOCK

Above: Contact sports like rugby union create a chance of head injury

Below: Concussion may be riskier for sportswomen than male counterparts

JONATHAN DANIEL/GETTY IMAGES



"It would be wrong to assume that a mild brain injury means it is trivial"

Need a listening ear? Turn to page 35 for details of helplines and websites

Graham Lawton is a features writer at *New Scientist*

KLAWE RZECZY

'Bennu samples may be rocks from an ancient ocean world'

Dante Lauretta leads NASA's OSIRIS-REx mission. He tells Joshua Howgego why he thinks the material it returned from the asteroid Bennu could be remnants of a planet once fit for life

ON THE morning of 24 September 2023, Dante Lauretta woke up early, his pulse racing. For 20 years, he had been working on a NASA space mission that aimed to scoop up a sample of an asteroid and return it to Earth. Now, it was time for the sample capsule to land. If anything went wrong, it could end up smashed to smithereens on the desert floor, as flat – and as useless to science – as a pancake.

Thankfully, the landing was successful. And since that day, researchers led by Lauretta, a planetary scientist at the University of Arizona, have been busily examining crumbly, jet-black material from the asteroid Bennu. Their mission, called OSIRIS-REx, is one of several similar efforts in what arguably adds up to a golden age of asteroid science. We now have no less than three pristine samples brought back from asteroids and there are thrilling plans afoot to visit others (see "Encounters with asteroids", page 42).

Lauretta has written a book about the OSIRIS-REx mission called *The Asteroid Hunter*. Here, he tells *New Scientist* about why asteroid samples are important, what his team has discovered so far and his jaw-dropping hypothesis that Bennu might be a fragment of a lost ocean world, one which may have had warm, watery conditions that could have made it an incubator for the building blocks of life.

Joshua Howgego: You watched from a helicopter as the OSIRIS-REx samples landed. How tense was it?

Dante Lauretta: I got up at 1.30 that morning because we had some routine work to do on the spacecraft. I wear a ring that measures my heart rate and I remember it was already 120 beats per minute! This was 20 years of my career, all depending on everything going smoothly on that day.

Later, I was in a helicopter, waiting for the capsule to come down. The capsule got pretty low and there should have been a drag parachute opening, but no one was calling it. I was a mess emotionally, thinking that this was going to be a disaster. But then the air force officer I was with was calling the main chute and, before I could process it, the capsule was safely on the ground. All this stress was released – years and years of anxiety and worrying and effort, pouring your heart into a mission – all of that lifted and I just broke into tears. It was relief, enormous relief.

Compared with planets and moons, asteroids might seem dusty and boring. Why is there so much interest in them?

Asteroids hold an enormous wealth of information, because they are literally the oldest rocks in the solar system. They represent the very first solid material out of which all the beautiful planets grew. That's why we find them so fascinating. They are the things that grew together to make up the planets, and the ones that are left are kind of the stragglers that survived the chaos of the early solar system.

We have had several asteroid sample-and-return missions already. Where does OSIRIS-REx fit into the story?

Well, it's the largest sample of asteroidal material ever returned to Earth, by a lot. We have in excess of 120 grams, more than twice what we promised. So that's super exciting for us.

This story started off two decades ago when we in the community were pushing to have a sample-and-return mission to a carbon-rich asteroid, so we could explore origin-of-life issues. We pitched it to NASA, the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA). And in the end, NASA and JAXA both funded missions, so it was a double victory. The Japanese missions became Hayabusa [which visited an asteroid called Itokawa] and Hayabusa 2 [which sampled the asteroid Ryugu], and we became very close teams.

As a community, we are ecstatic that we got these three opportunities. The samples are similar yet distinct, so there's interesting

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> "Asteroids hold the very first solid material out of which all the beautiful planets grew"

things to learn there. Why is Ryugu different than Bennu? Did they come from the same asteroid family? There's a good chance that they did and we're sampling various regions of a much, much larger world.

In your book, you call Bennu "the most dangerous rock in our solar system". Why?

We rank the hazardous asteroids based on the impact probability, and Bennu has the highest probability of impacting the Earth of any known object. The odds are 0.05 per cent, so pretty low as these things go, right, but not zero. It's 500 metres in diameter, so it would not be an extinction level event; it's a regional disaster. But, nevertheless, it would be a big deal.

What does that 0.05 per cent probability really mean?

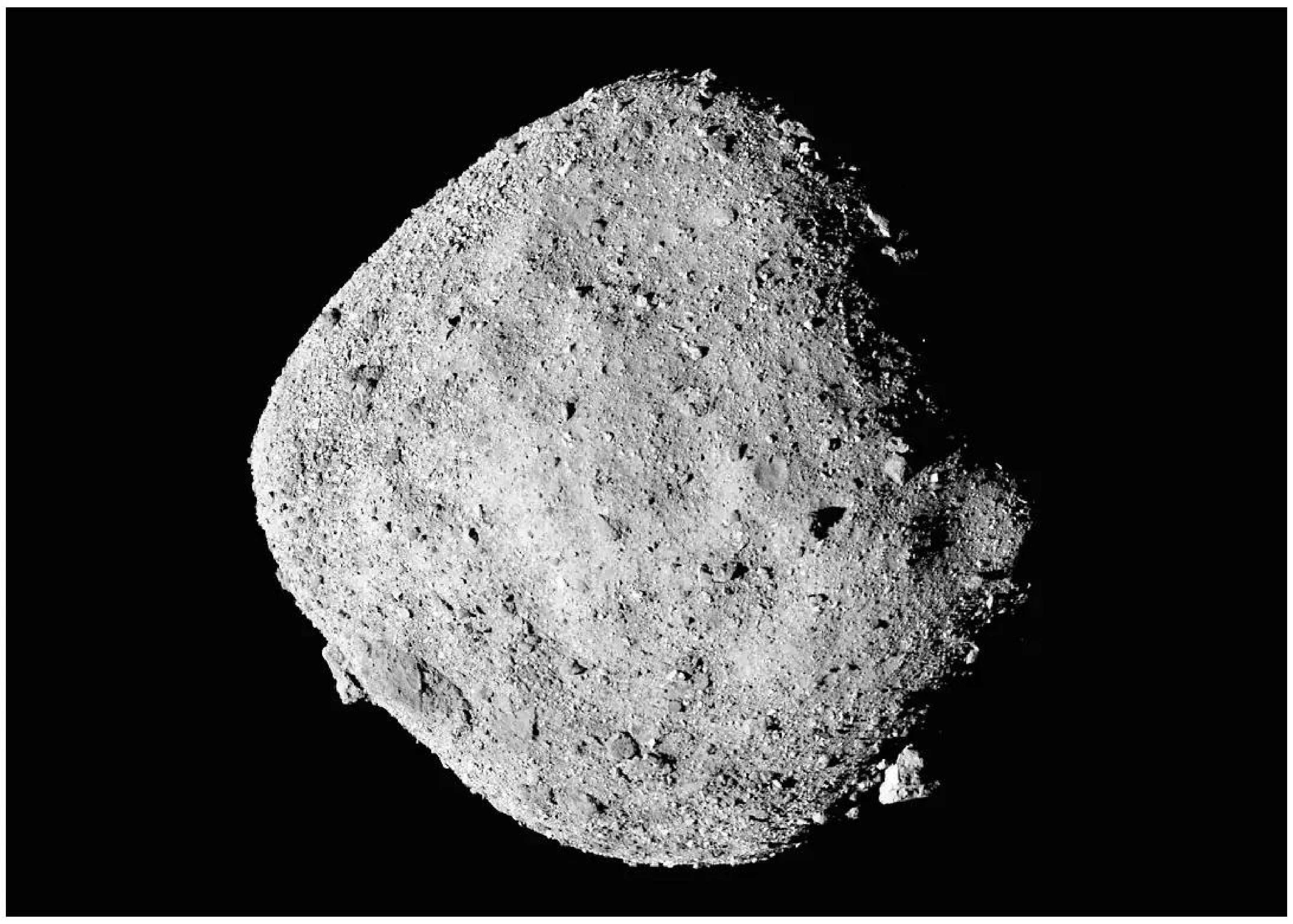
We know Bennu's orbit exceedingly well and we can trace it to 2135. We will be all right until then, at least. But at that point, Bennu is going to come in between the Earth and the moon. That's where the uncertainty blows up, because of small variations in the time and location of that encounter with the Earth. We have tried modelling what happens to Bennu if we put it in lots of different places at that point, and that probability refers to the chances of it hitting the Earth then.

I wish I could live until the year 2135, because there'll be a resurgence of interest in asteroid Bennu.

What have you learned from the material from Bennu so far?

When you look at the material, most of it looks dark, like charcoal, but there is also some really bright stuff, which, to me, is the most exciting thing we got. Let me try to explain.

One of the first things we did was analysis using a technique called X-ray diffraction, which gives you peaks on a graph that correspond to a known mineral. The sample of Bennu is mostly made up of water-bearing clay, specifically minerals called serpentines. There's the same rock type on Earth, which forms when mantle rock hits ocean water. Then we also found that we have this



NASA/GODDARD/UNIVERSITY OF ARIZONA

OSIRIS-REx returned a sample of the asteroid Bennu

Encounters with asteroids

A rundown of our missions to study asteroids, past, present and future

HAYABUSA
JAXA
Launched: 2003
The first attempt at an asteroid sample-and-return mission brought back less than a milligram of material from asteroid Itokawa in 2010.

HAYABUSA 2
JAXA
Launched: 2014
Returned in 2020 with 5.4g of material from Ryugu.

OSIRIS-REX
NASA
Launched: 2016
Brought back about 120g of material from asteroid Bennu in September 2023.

PSYCHE
NASA
Launched: 2023
In transit towards Psyche, which is thought to be a metallic asteroid. It should arrive in 2029, but won't bring back samples.

MARTIAN MOONS EXPLORATION (MMX)
JAXA
Due to launch: 2026
MMX will travel to the Red Planet's two moons, Phobos and Deimos, and collect a sample from the former to return to Earth.

MBR EXPLORER
UNITED ARAB EMIRATES SPACE AGENCY
Due to launch: 2028
This mission, currently in development, plans to visit seven asteroids in the belt between Mars and Jupiter, as well as dropping a lander on Justitia, a 50-kilometre-wide asteroid in the asteroid belt.

NASA

Researchers taking pieces of the Bennu sample from the returned cannister

magnesium-rich phosphate mineral, and this is what makes up those bright sections that I mentioned. This is really rare and it's also a weird type of phosphate that I have never seen before. It's very, very uncommon in geologic settings.

Can you tell me more about why the bright stuff is so interesting?
The thing about the phosphate material is that it looks very odd. It appears like a thin skin that looks like it has been deposited on the material. I was really puzzled by this, so I put out a call to the community, asking: "Has anybody seen this in geologic environments?" I heard from a group that detected sodium phosphate particles in the plumes of water erupting from Enceladus [a moon of Saturn] during the Cassini mission.

So if I put it all together, Bennu samples are hydrated, organic-rich serpentines from the early solar system. Serpentines on Earth, at least, form when rocks from the mantle are forced upwards into the seabed and react with water, in a reaction that releases heat – and it was probably a similar process on Bennu's parent asteroid. So we clearly had a set of rocks that were interacting with a carbonated fluid. That's a huge result to me.

I would say my working hypothesis – and you know, if we can prove it, it's huge – is that Bennu samples are rocks from an ancient ocean world. You would have had phosphate enrichment in the fluid and, ultimately, evaporation and precipitation of that phosphate material.

Phosphate is a key building block in biology, right?
That's right, phospholipids make our cell walls and adenosine triphosphate is the primary energy molecule for all life on Earth. Phosphate molecules also form the backbone of DNA and RNA, and so are critical to our genetic material.

Did you find anything else interesting?
We can also see these things I call nano-globules all over the place. These are spheres with walls of carbon and nitrogen, sometimes empty and sometimes with other phases of mineral or rock inside them. They're enormously abundant. We see them all over this material. These are exciting from an origin-of-life perspective. These could be like a protocell.

Presumably you aren't suggesting that these were living, but what do you think the significance of these nano-globules is?
We're starting to unravel that. I think these are like [spheres made of surfactants called] micelles, so they were probably once suspended in fluid. Think of them like oil droplets in water. It's early days and origin of life is a big area of investigation with these samples. They might be telling us something important, at least about compartmentalisation. If you can get separation of chemical systems, that's the first step towards a cell and that's where metabolism could maybe start to originate.

Some people dream about sending a mission to the ocean floor of Enceladus. But it sounds like what you are saying is that we have almost got that kind of sample in our hands already.
That's my hypothesis; I haven't proved it yet. And look, I love the idea of going into the ocean of Enceladus or Europa, a moon of Jupiter. I wouldn't want to not do that, you would learn so much. But I think, at the very least, we have an abiotic sample of an ancient alkaline hydrothermal system, which means we can explore the hypothesis that critical organic molecular evolution may have taken place in those environments on the early Earth.

The point is, when we look at locations on the early Earth where we think life could have originated – such as hydrothermal vents at the mid-ocean ridge, the white smokers, for example – there's biology all over the place, right? There's worms and crabs and bugs and sea snails. So you can't tell which molecules are building blocks for life and which have been synthesised by living things. With Bennu samples, we don't have that problem.

What about amino acids, the building blocks of proteins – have you found any of those?
This is so interesting. We have found some and the results are fascinating, but they're under review for publication, so I'll have to leave you in suspense for now.

OSIRIS-REx isn't entirely finished yet, is it? Tell me about what's next for the spacecraft.
One of the mission designers came to me a few years ago and said: I can get you to Apophis, which is a famous asteroid in our community. Normally, when you're talking about an extended mission, spacecraft can just do a flyby. But he said, I can get you into orbit around Apophis. I was stunned and super excited. It will arrive in 2029 and rendezvous with that asteroid. It's an S-type ("stony") asteroid, which is the second most common type, and we'll be able to do a nice comparative study between Bennu and Apophis using exactly the same payload of instruments. ▮

Joshua Howgego is deputy head of features at *New Scientist*

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The science of baking

Party time

Keeping your chocolate cake moist and delicious when you make it party-sized is tricky, but not impossible, says **Catherine de Lange**

Catherine de Lange is the editor of *New Scientist* and an avid baker

What you need

Ingredients for one 20-centimetre (8-inch) round cake (I will bake three):
190 g (1½ sticks) butter
190 g (6¾ ounces) dark chocolate
4 tsp instant coffee
140 ml (½ cup) water
110 g (¾ cup) self-raising flour
110 g (¾ cup) plain or all-purpose flour
40 g (⅓ cup) cocoa powder
¼ tsp bicarbonate of soda (baking soda)
420 g (2 cups) caster sugar
3 eggs
2 tbsp vegetable oil
95 ml (⅓ cup) buttermilk

NEXT week is my daughter's 5th birthday party, and she has high expectations for her cake. It has to be extremely chocolatey, but it must also be a "piñata cake", meaning that when you cut into it, sweets cascade out. It will also have to be large, to serve 30 children and their chaperones.

My big worry is that it could end up very dry. To achieve the required size and the piñata effect, I will have to bake at least three large layers, but I will also have to cut out the middle of the cake, which, as we all know, is the best part, leaving only the drier edges.

So how do I give myself the best chance of avoiding a dry cake? First, the recipe. I am choosing one with lots of wet ingredients to help boost moisture levels. When it comes to the fat you use in baking, the most common choices are oil or butter. I normally go for butter because it is more delicious, but oil is liquid at room temperature, which means a softer sponge. So, I am including both, as well as buttermilk for more moisture.

To make it really chocolatey, I will use both a good-quality cocoa powder and melted dark chocolate. Using cocoa means a bit less flour is required, and the chocolate is higher in fat, so it should add to the richness and moisture. Adding coffee also helps to amplify the chocolate flavour. Melt the chocolate and the butter together in a pan with the coffee and the water, then set aside.

SHUTTERSTOCK/JACLYN VERNACE

Sift the dry ingredients into a bowl and make a well in the centre. Add the combined eggs, oil, buttermilk and melted chocolate and stir until combined. Avoid overmixing as this can cause an excess of gluten strands, which leads to a tougher texture.

Now onto the baking. A cake bakes from the outside in, which is why the edges tend to be drier than the middle. To counter this, I have been testing ways to keep the edge of the cake cooler in the oven. My preferred option is to create a collar around the tin that protects and cools the edges as it bakes. You can buy special baking strips for this, but I prefer making my own. Take a piece of paper towel that is at least as long as the circumference of your tin. Wet it completely and then squeeze out most of the water. Unravel it gently, and lay on a piece of tin foil of the same length. You might need to fold the towel in half along the length, so it is about the same height as your tin. Then fold the tin foil over the paper towel until it is encased within the foil and wrap this collar around your tin. Grease the inside of the tin, line with baking parchment and pour in your mix. Bake in a 160°C (320°F) oven for around 1 hour, or until a skewer inserted into the centre comes out clean.

For a piñata cake, use a round cake cutter or knife to remove the middle of each cake except the top layer. Fill this hole with candy, pop the final layer on top to conceal it, and decorate. Then watch as 30 children destroy it! ▮

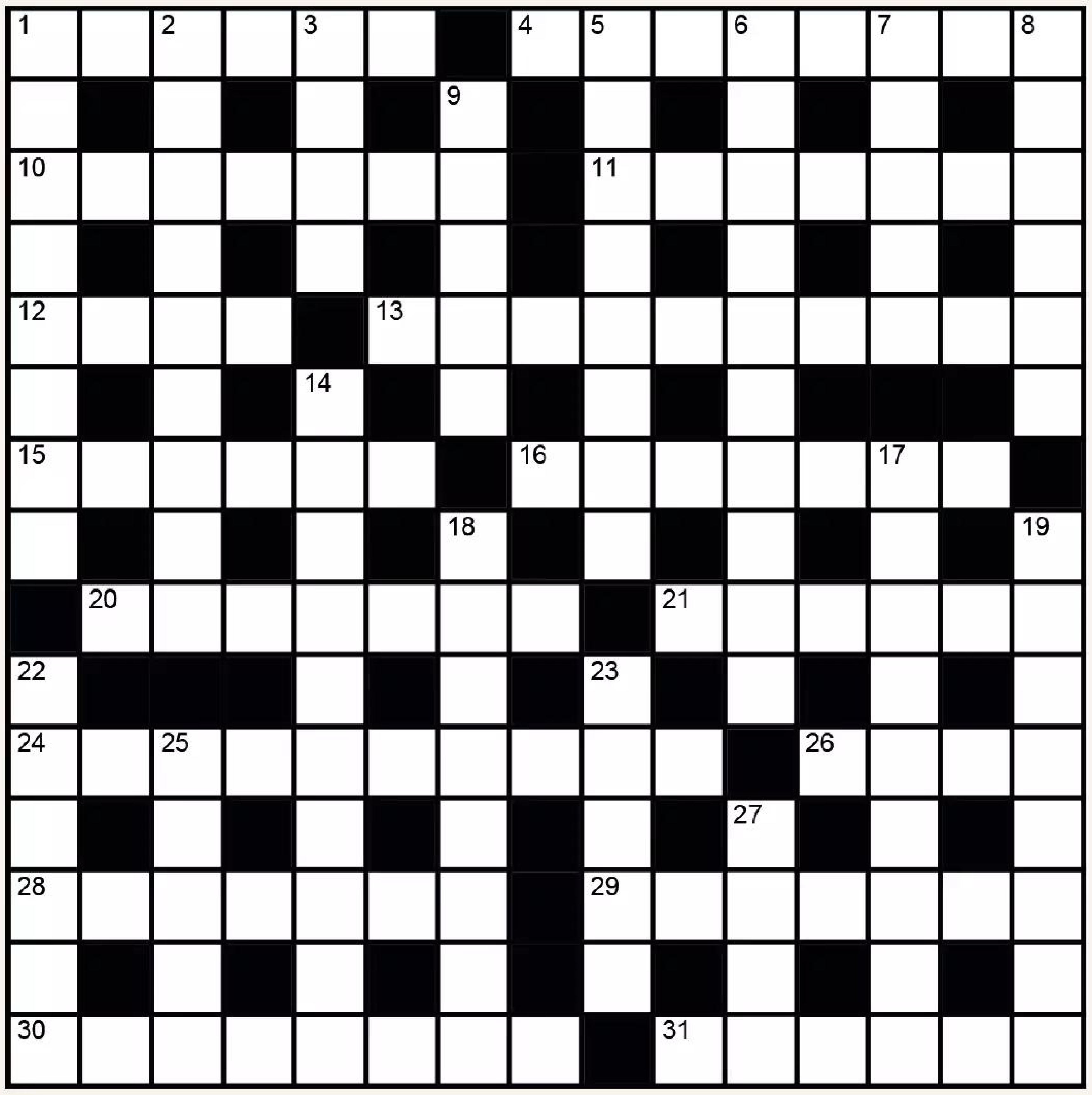
Watch Catherine create her baking collar at newscientist.com/maker

The science of baking appears monthly

Next week

Stargazing at home

Quick crossword #153 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Distant (6)
4 Cephalalgia (8)
10 Contained microbiological growth (7)
11 Breathe in (7)
12 Cipher (4)
13 Fight-or-flight hormone (10)
15 Jenner or Teller, perhaps (6)
16 Bitumen (7)
20 Nuclear species of an element (7)
21 ___ fly, parasitic African insect (6)
24 Arboreal bird that might be green or ivory-billed (10)
26 Circle, ring (4)
28 Tropical tree with lobe-like leaves (3,4)
29 Three-leaved shape (7)
30 Giving off vapour (8)
31 Subatomic particle (6)

DOWN

1 Bounce off (8)
2 Collapse (nuclear or emotional, perhaps) (9)
3 Heavy noise (4)
5 Neurological condition that causes seizures (8)
6 Congenital skull condition, also called cranioschisis (10)
7 Novels, stories or comics about climate change (3-2)
8 First repdigit (6)
9 Flexible (5)
14 Living part of a cell (10)
17 Removal of kidney stones (9)
18 Sample (8)
19 Airship (8)
22 Fast-flying migratory birds (6)
23 δ (5)
25 Imperial unit of weight (5)
27 ζ (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #242

set by Bethan Ackerley

1 The disease pellagra is caused by a deficiency of which vitamin?

2 Which of the following isn't a module of the International Space Station: Harmony, Tranquility or Freedom?

3 The group of plants commonly called spurge belong to what genus?

4 Lunar maria, large plains on the moon, are predominantly formed of what kind of rock?

5 Tarsier and simian primates are grouped together in which suborder?

Answers on page 47

BrainTwister

set by Peter Rowlett

#10 Chairs in pairs

Abbie and Bryn are allocated places to sit at random in a row of four seats. What is the probability that they are put next to each other?

What if there are 20 seats?

On a different occasion, Abbie and her friend Ana have booked two adjacent spots on the front row, which is 22 seats long. Bryn and his friend Beth also have two adjacent seats among the 22. What is the probability the two groups are next to each other?

Solution next week

Crash landing

If an object hadn't crashed into Earth to form the moon, as is hypothesised, Earth would be bigger. Would it still sustain life?

Ron Dippold
San Diego, California, US
You reference the giant impact hypothesis, the most favoured explanation for the moon's existence and composition.

It suggests that, about 100 million years after our solar system started to form, proto-Earth got smacked by Theia, a Mars-sized planet. This knocked enough debris into orbit to form the moon. The early solar system was so crowded and chaotic, it was like the seven-lane "Magic Roundabout" in Swindon, UK, if all the drivers were drunk. It is thought that early Earth had dozens of small planet impacts and Theia was the last major one, though it continued to be bombarded by tons of comets and meteorites.

But the key word here is "Mars-sized". Mars and the hypothetical Theia are a tenth of Earth's mass. Our moon is only a hundredth of Earth's mass. Theia is thought to have hit our world pretty square on, so the bulk of it would have sunk into Earth, which would have actually gained up to about 10 per cent mass from this impact.

> "The early solar system was so crowded and chaotic it was like the seven-lane 'Magic Roundabout' in Swindon, UK"

Without the moon, we wouldn't have our tides. Some think that these helped start life by repeatedly refreshing (at high tide) and concentrating (at low tide) life's starter components in tidal zones. So maybe we wouldn't have life in the first place without the moon. There are lots of other ideas about how life began, though.

If life would have still started on Earth without the moon, a mere 10 per cent increase or decrease in mass would be entirely survivable – though dieters might either be distraught or ecstatic.

SARAYUT THANEERAT/GETTY IMAGES

This week's new questions

What a downpour **While sheltering from a huge storm, I wondered whether there is a limit to how hard it can rain.**
***Nigel Stace**, Charlestown, New South Wales, Australia*

All that glitters **Why do humans like sparkly things?**
***Derek Johnson**, Moreton in Marsh, Gloucestershire, UK*

What is the hardest it can rain, or is there no limit to the force of a downpour?

Mike Follows
Sutton Coldfield, West Midlands, UK
There are several conditions that make life possible on Earth and most or all were present before the hypothetical impact that created the moon. It is possible life would have flourished even without it.

Liquid water is required for the biochemical reactions essential to life as we know it. Luckily, our planet orbits at a distance from the sun that is inside the habitable (or "Goldilocks") zone, where Earth's global mean surface temperature allows liquid water to collect on the surface. The planet's magnetic field protects our atmosphere by deflecting solar wind; the depletion of Mars's atmosphere can be traced back to the collapse of its magnetic field. Earth is massive and dense enough to produce a sufficiently strong gravitational field to prevent the escape of our atmosphere, but has this always been the case?

According to the giant impact hypothesis, a planet called Theia collided with proto-Earth and, out of the wreckage, we ended up with our moon orbiting a more massive Earth. The mass of Theia has been proposed at between 10 and 45 per cent of the current mass of Earth. This implies that, before the collision, Earth had a mass of between 56 and 91 per cent of what it is today. Assuming Earth's density hasn't changed, the gravitational field strength on the planet's surface would have been as low as 82 per cent of its current value. Earth's escape velocity may have been as low as 9.2 kilometres per second (compared with our current 11km/s).

The exosphere is where our atmosphere blurs with outer space. The bottom of the exosphere is called the exobase and its height varies between 500 and 1000 km above Earth's surface. In the atmosphere, gas particles constantly collide with each other. If they are moving away from Earth's surface with the required escape velocity when they reach the exobase, they will never again collide with another terrestrial gas particle and will be lost forever from Earth's atmosphere. This is a bit like evaporation from the surface of a liquid.

Due to heating by ultraviolet radiation from the sun, the temperature at the exobase is about 1000 kelvin. At this temperature, hydrogen atoms have an average speed of about 5 km/s (below Earth's escape velocity of 10.8 km/s at the exobase). But there are enough fast atoms that 3 kilograms of hydrogen escapes the atmosphere every second, which is insignificant. A significant loss of hydrogen risks drying out the planet.

This is known as Jean's escape. A less massive Earth would mean a smaller escape velocity and potentially more Jean's escape. However, according to the faint young sun paradox, when Earth was formed, the luminosity of the sun would have been about 30 per cent less than it is today, so the gas particles in the atmosphere would have been travelling slower. Regardless, even a thinner atmosphere would probably have been sufficient to sustain life.

The luminosity of the sun is increasing by 10 per cent every billion years. As Earth warms, the stratosphere will get wetter,

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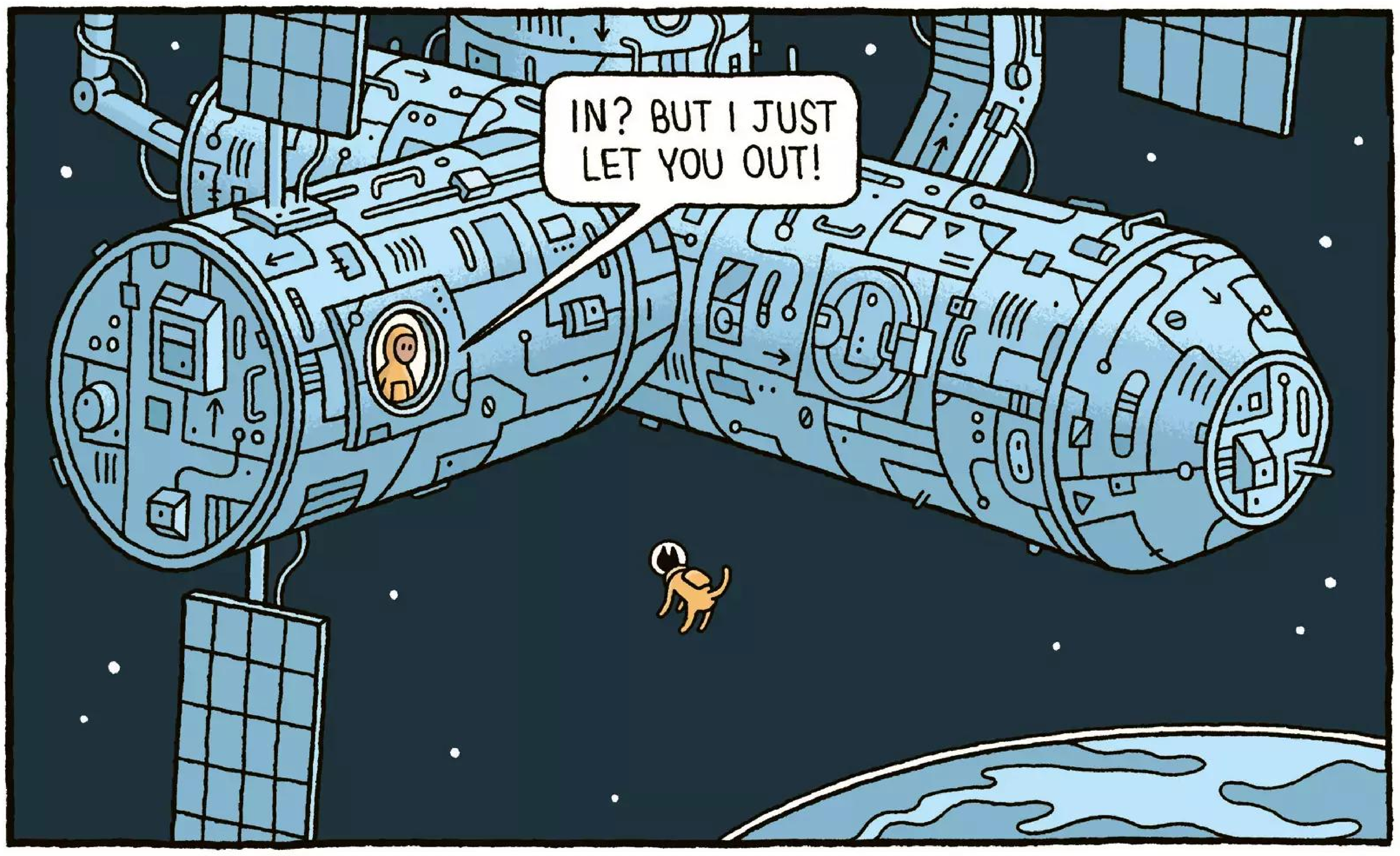
IN? BUT I JUST LET YOU OUT!

increasing the diffusion of water vapour upwards towards the exobase. Geoscientist James Kasting predicted Earth will have lost most of its oceans in 2 billion years. The bigger the mass we gained from the Theia impact, if it occurred, the longer this nightmare scenario is postponed.

The existence of the moon is the wild card. The tides produced by the moon lead to the alternate wetting and drying of the intertidal zone, which may have been crucial for the origin of life, so perhaps the impact was vital after all.

Sense of direction

How did Roman road builders know which way to go? If they were a few degrees out setting off from, say, Chichester, they could have ended up in what is now Slough, not London. (continued)

Bryn Glover
Kirkby Malzeard,
North Yorkshire, UK

I have seen demonstrated, albeit on a small scale, a technique said to have been employed by Roman road engineers. Before constructing Stane Street, they would have had a good idea of the general direction to get to London or Chichester from either end.

> **"I have seen a small-scale demonstration of a technique said to have been employed by Roman road engineers"**

They sent out teams of soldiers (of which they had thousands) along the guessed alignment from each starting point, so each team could see the flag held up by the teams either side of it.

Each team was equipped with pairs of simple aligning rods. They would sight on the flags, seeing an obtuse angle (90° to 180°) and a reflex angle (180° to 360°) between them. The soldiers would then move sideways in the direction of the obtuse angle, and so on. Eventually, the teams would shuffle themselves into a straight-line orientation.

Where difficult features such as rock outcrops or river confluences happened to coincide with the final line, the engineers would deliberately move the alignment to miss such features and order new shuffles to find the new shortest route.

Safe time travel

When I invent a time machine, what is the earliest period in Earth's history in which I could comfortably survive? (continued)

Hillary Shaw
Newport, Shropshire, UK

Maybe no more than a millennium or two earlier. It is easy to miss the effects of the unseen microbiome, the panoply of bacteria and viruses around us. Some can make us ill, but many are crucial to our health. The further back (or forwards) you go, the more different this microbiome will become, and you risk being exposed to novel diseases your immune system has no experience of. ▮

Answers

Quick quiz #242
Answers

1 Niacin, or B3
2 Freedom
3 *Euphorbia*
4 Basaltic
5 Haplorhini

Cryptic crossword #130 *Answers*

ACROSS 1 Maple, **4** Gentian, **8** Colloid, **9** Recut, **10** Mobile device, **12** Excite, **14** Dangle, **17** Constraining, **21** Alexa, **22** Balloon, **23** Plaster, **24** Dusty

DOWN 1 Macs, **2** Paleo, **3** Egotist, **4** Gadget, **5** Nurse, **6** Inching, **7** Nattered, **11** Leg cramp, **13** Candela, **15** Annelid, **16** Camber, **18** Tract, **19** Nooks, **20** Only

#9 Rectangulator
Solution

From the 7, we can go round a rectangle, with width or height 1 or 2, in either direction. Eight numbers are possible: 7854, 7821, 7964, 7931, 7458, 7469, 7128 and 7139. If you allow zero width/height, you can also have 7777, 7887, 7997, 7447 and 7117. For zero-height or width rectangles, the first two digits are the last two digits reversed. This will always be a multiple of 11, since it will be a sum of multiples of 110 and 1001, both multiples of 11. If we extend the rectangle, we move both numbers horizontally or vertically by the same distance. Instead of 7117, we could extend to the right and get 7128. This won't affect whether it is a multiple of 11, as we are adding or taking away 11 per column we move. Likewise, extending a zero-height rectangle horizontally, we just add or subtract 33 per row we move.

Time for love

Valentine's Day celebrates coupling. Alan McWilliam tells Feedback about an offer he received, before the most recent Valentine's Day, from a US-based biotechnology company. It couples charm with other qualities.

Alan says: "I received the marketing email below. I've never been offered a 'complimentary breeding pair of genetically modified mice' for Valentine's Day before. What says romance more than gazing into your mouse's eyes, over a Bunsen burner flame, before implanting a tumour and humanely euthanising it a few weeks later?"

This is the note:

"Dear Alan,

Love is in the air, and at [REDACTED], we're sharing the love with a special Valentine's Day promotion just for you! 💝

Theme: Perfect Pairings in Research

Promotion: This Valentine's Day, Receive a Complimentary Breeding Pair of Genetically Modified Mice with Our Gene Targeting Services. 🐭🐭

Coupon Code: FREECOUPLE

This limited-time offer is designed to enhance your research and provide you with the perfect research companions."

Whatever this offer may accomplish for romance or commerce, its most powerful use could be as a psychological test. How does a person respond, at first blush, to this opportunity?

Political restraint

A growing treasury of top-dog data almost begs UK psychology researchers to sift it for lessons about leadership. Feedback infers this from news accounts.

The *BMJ* (formerly formally called *The British Medical Journal*) makes medical note of news reports that prime minister Rishi Sunak "fasts for 36 hours at the beginning of every week". Sunak's past and present medical data might intrigue and inspire physicians, psychologists and nutrition researchers. Over time, does the body in evidence inflate or deflate? How much of that inflation or deflation can be attributed to the leader's first-person management of food?

More complete data may already be available about the effects and effectiveness of self-imposed restraint (or at base, self-claimed restraint) by former prime minister David Cameron, who held office and his urine from 2010 to 2016.

New Scientist's report in 2015 about Cameron fluidics explained: "Before important speeches or negotiations, Cameron keeps his mind focused by refraining from micturating. The technique may be effective – but it also appears to help people to lie more convincingly."

(In a happy twist of serendipity, the 2011 Ig Nobel medicine prize was awarded to researchers in the UK, the Netherlands, Belgium, Australia and the US for testing the effectiveness of the delayed-urination technique. That award was made bare weeks before Cameron revealed his pee proclivity to the public.)

Additional varieties of data will be tappable by researchers, should it some day become apparent that other UK prime ministers also exercised restraint.

Twisteddoodles *for New Scientist*

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Down the tarantula hole

Juicy, surprising delights about living things sometimes lodge in the reference sections of scientific papers about long-extinct things.

Trilobite researchers still chatter about the study "Frontal auxiliary impressions in the Ordovician trilobite *Dalmanitina* Reed, 1905 from the Barrandian area, Czech Republic", published a few years ago in the *Bulletin of Geosciences*.

But only the most diligent of them noticed – deep in the references section, at the end of the paper – something unexpected: mention of a paper called "Coupling between the heart and sucking stomach during ingestion in a tarantula" by Jason Dunlop, John Altringham and Peter Mill, published in 1992 in the *Journal of Experimental Biology*.

And deep inside that heart/sucking-stomach paper lurks a different kind of surprise, a reminder that scientists need to proceed always with caution: "In the absence of detailed information about fluid flow in tarantulas, any model is speculative."

Tender youth

Dave Kirby has noticed another cookbook that, like *The Anarchist Cookbook*, maybe needs to come with a warning (Feedback had suggested something along the lines of: "If you don't cook your anarchist to the proper temperature, there may be problems").

Dave says: "In addition to the books you mentioned, you could add *The River Cottage Baby and Toddler Cookbook*. A local restaurant has a bookshelf full of cookbooks and I spotted this one there months ago.

"I hesitated to look too closely into the small print on their menu."

Depending on cats

Comforting news, maybe, for people who dread any temporary absence from their cats.

A study from California called "A comparison of people's attachments to romantic partners and pet cats," published in the journal *Anthrozoös*, reports that some people "did not necessarily need reassurance from their cat or feel distress when their cat was unavailable to them the way they might about a romantic partner". ▮

Marc Abrahams

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